Syllogeus 51

Climatic Change in Canada 4

Annotated Bibliography of Quaternary Climatic Change in Canada

C.R. Harington and G. Rice, Editors

Compiled by Anne B. Smithers,
Linda Ghanimé and C.R. Harington

National Museums of Canada
Musées nationaux du Canada

National Museum of Natural Sciences
Musée national des sciences naturelles

88-03281/

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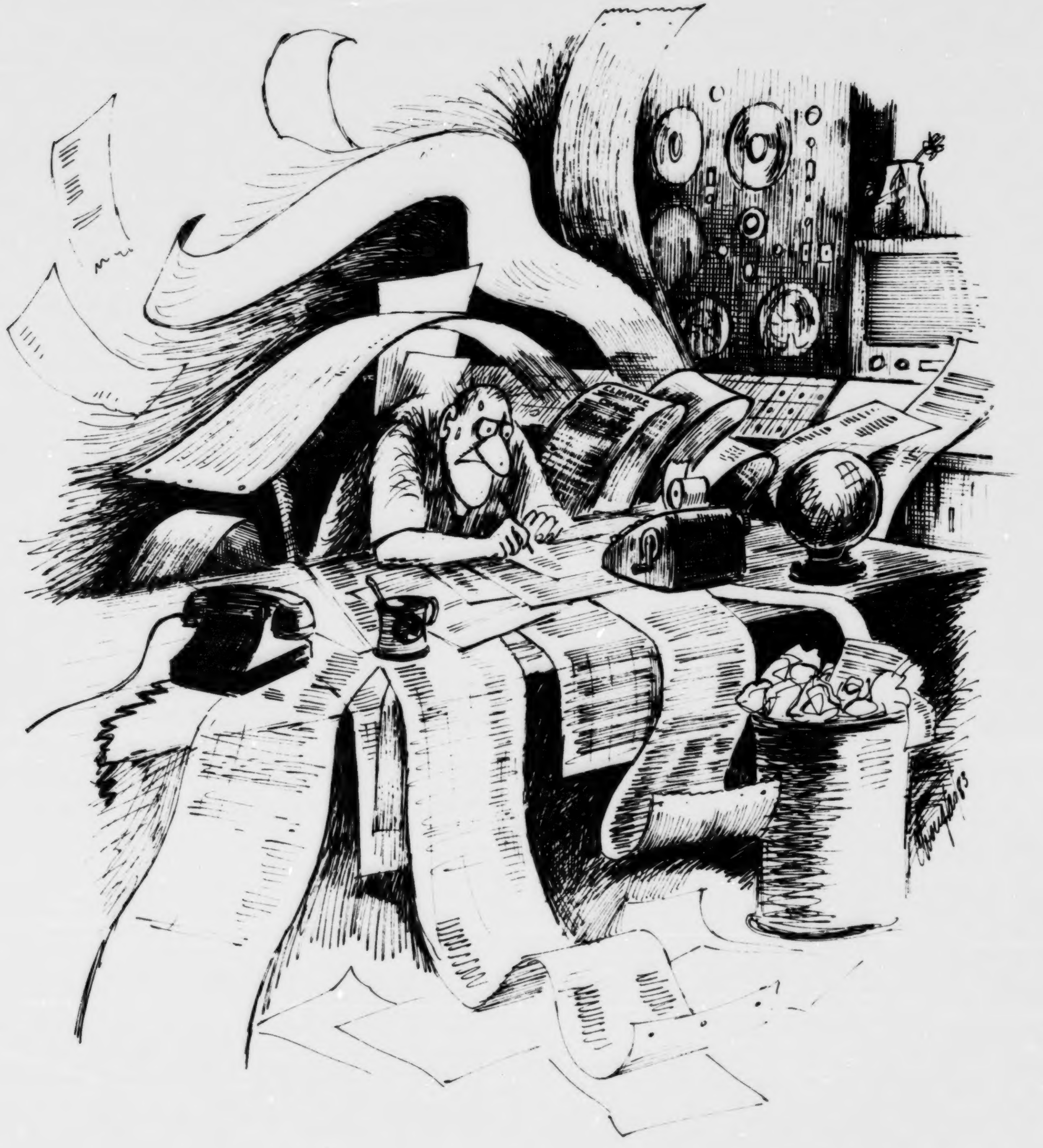
Syllogeus Series No. 51
(c) National Museums of Canada (1984)
Printed in Canada
ISSN 0704-576X

Serie Syllogeus No. 51
(c) Musées nationaux du Canada (1984)
Imprimé au Canada

CLIMATIC CHANGE IN CANADA 4



INSIDE COVER ILLUSTRATION

BY CHARLES DOUGLAS

CLIMATIC CHANGE IN CANADA 4

ANNOTATED BIBLIOGRAPHY OF QUATERNARY CLIMATIC CHANGE IN CANADA

National Museum of Natural Sciences
Project on Climatic Change in Canada
During the Past 20,000 Years

Edited by C.R. Harington and G. Rice
Compiled by Anne B. Smithers, Linda Ghanimé and C.R. Harington

Syllogeus No. 51

National Museums of Canada
National Museum of Natural Sciences

Les Musées nationaux du Canada
Musée national des sciences naturelles

ACKNOWLEDGEMENTS

The editors are grateful to: Mr. C.G. Gruchy (Acting Director, National Museum of Natural Sciences) and Ridgeley Williams (Acting Assistant Director, Research and Operations, National Museum of Natural Sciences) for their support; colleagues in the Paleobiology Division for their continuing interest in and encouragement of the project, and particularly Anne Smithers and Linda Ghanimé who undertook the arduous work of compiling and typing drafts of this publication. Linda Ghanimé's work was greatly facilitated by Dr. Sven Orvig (Dean of Science, McGill University), who arranged for library access and work space, and Dr. Pierre Richard (laboratoire de palynologie, Université de Montréal), whose private reprint collection provided an excellent source of information. Mr. A. Stewart (National Museum of Natural Sciences Branch Librarian) kindly obtained additional citations by a computer search of the GEOREF database and assisted by arranging interlibrary loans. Martha Andrews (Principal Investigator, Annotated Bibliography of Holocene Climates, Department of Geological Sciences, University of Colorado, Boulder) and Professor C. Wilson provided useful advice on organizing the index.

In 1982, a generous grant was received via Atmospheric Environment Service, which had been allocated extra resources to develop specific areas of the Canadian Climate Program, including work undertaken by the NMNS climatic change project. These funds were sufficient to allow completion of work on this bibliography, and the first editor sincerely thanks Morley K. Thomas and Gordon McKay of the Canadian Climate Centre for their assistance.

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INTRODUCTION

C.R. Harington[1]

PURPOSE

Since its beginning in 1977, a basic aim of the National Museum of Natural Sciences climatic change project was to compile "a comprehensive, annotated bibliography on the subject" [of Quaternary paleoclimates in Canada] - in addition to supporting research in this field and publishing paleobiological, historical and meteorological data of significance to the study of climatic change in Canada since the peak of the last glaciation some 20,000 years ago (Harington 1980, p. 13). I hope that this annotated bibliography will: (1) serve as a "refresher" on sources, as well as being a useful research tool for professionals; (2) act as an introduction to references on climatic change in Canada during the last 2 million years (Quaternary) for laymen and students interested in this topic and for scientists beginning work in this field; (3) give some idea of the diversity of disciplines contributing published paleoclimatic data; and (4) demonstrate the acceleration of research in this field during the last few decades, as well as indicating some strengths and weaknesses of such research, where geographic, geochronological and disciplinary coverage is concerned.

Fundamental to this work is a belief that a knowledge of past climate if carefully accumulated and interpreted, can lead to a better understanding of the nature, timing and strength of future climatic alterations. Regardless of the predictive value, we believe that the results of past work on Quaternary climatic change in Canada, only imperfectly indicated in this publication, will be of interest and value academically (e.g. to biogeographers, paleoecologists, archaeologists and historians).

BACKGROUND

Most of the work on this bibliography was carried out by two graduate students, Linda Ghanimé and Anne Smithers, working on contract under my supervision. During the period November 1 - March 31, 1979, Linda Ghanimé compiled about 500 annotations - mainly from sources in Montréal (Physical Science, Meteorology, Blacker-Wood, Botany and Genetics, McLennan libraries of McGill University; Centre for Northern Studies and Research Library, Collection du laboratoire de palynologie, Université de Montréal; Bibliothèque des Sciences, Université du Québec à Montréal; and the Science and Engineering Library, Concordia University). Prior to her work, I did not realize how diverse and abundant references were on this subject, nor how far back in time of publication they extended.

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[1] Paleobiology Division, National Museum of Natural Sciences, National Museums of Canada, Ottawa, Ontario K1A 0M8

Anne Smithers worked on the bibliography during the periods September 1, 1981 - July 31, 1982 and January 1 - March 31, 1983. She not only checked Linda Ghanimé's annotations and rewrote many of the earlier annotations, but greatly augmented and improved the bibliography (bringing the total number of annotations to 912) by: (1) cross-checking reference lists in the most important papers to see if some sources were being missed; (2) making annotations of pertinent references found in the GEOREF computer listing for 1961-1981 that applied to this topic[1]; (3) updating the annotations by checking current issues of the most important journals containing papers on Quaternary paleoclimates in Canada (e.g. *Arctic; Arctic and Alpine Research; Canadian Journal of Earth Sciences; Climatic Change; Palaeogeography, Palaeoclimatology, Palaeoecology*); (4) renumbering the annotations that were finally selected and listing key words for each; and (5) preparing the final index. The main information sources used by Anne Smithers are in Ottawa (e.g. National Museums of Canada, Carleton University, Geological Survey of Canada, and Agriculture Canada libraries). Mr. A. Stewart of the National Museums of Canada Library was most helpful in arranging for interlibrary loans of references that were difficult to obtain.

I was responsible for planning the bibliography, supervising the work of the contractors, selecting annotations to be included (substantial published papers with references were given priority over published abstracts and unpublished material such as theses), contributing some annotations, organizing the index (with valuable advice from the contractors, Martha Andrews and C. Wilson), and editing the text to fit *Syllogeus* format. The latest references in this volume date to early 1983. Mrs. Gail Rice assisted me in editing the publication, and effectively carried out liaison with Sussex Informatics, who held the contract for word-processing of the manuscript.

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[1] The most useful key words in searching were: Canada (or province or territory names); Quaternary; Pleistocene; Holocene; and paleoclimatology.

ORGANIZATION

Annotations

Annotations are listed in alphabetical order by author's (or first author's) surname and date of publication. Each annotation is preceded by a number for ready reference and to make the index at the end of the volume more succinct.

Abbreviations following the annotations indicate their sources:

A.A. - Author's abstract.

A.B. - Arctic Bibliography (Arctic Institute of North America) abstract.

A.B.S. - Abstract prepared by Anne B. Smithers.

A.C. - Author's conclusions.

A.I. - Author's introduction.

A.S. - Author's summary.

A.S.C. - Author's summary and conclusions.

C.R.H. - Abstract prepared by C.R. Harington.

D.A.I. - Abstract taken from Dissertation Abstracts International.

Editor - Editor's summary.

Excerpt(s) - Abstract prepared by extracting relevant sections from text.

G.A. - Abstract taken from Geo Abstracts.

L.G. - Abstract prepared by Linda Ghanimé.

P. - Abstract taken from preface.

p - Relevant portion of work abstracted (e.g. pA.A. means relevant portion of author's abstract).

***** - Includes other relevant information (e.g. annotator's comment enclosed by square brackets).

Thomas - Abstract taken from *Meteorological studies of climatic fluctuations in Canada, 1917-1960. An annotated bibliography*, prepared by M.K. Thomas (1975).

Index

The index is organized by: (1) **Geographical region** - alphabetically according to province and territory names ("Northwest Territories" is divided into "Islands" and "Mainland" categories for ease of reference; see map, Figure 1), "Canada - General" (where annotations deal with Canadian areas larger than natural regions), "North America" (annotations dealing with Canada and other parts of North America), and "Global" (annotations dealing with Canada and other parts of the world); (2) **Geological time** - "Quaternary" (approximately the last 2 million years), "Pleistocene" (approximately 2 million years ago to approximately 10,000 B.P.[1]), "Holocene - Prehistoric" (approximately 10,000 B.P. to approximately 500 B.P.), and "Holocene - Historic" (approximately 500 B.P. to the present) (Figure 2); (3) **Subjects** - nearly 40 names of disciplines or topics are listed alphabetically (following the "General" category). Some subjects (e.g. "Climate" and "Geology") are subdivided for greater precision of reference (Table 1).

CONCLUSION

This is a preliminary attempt at establishing a source of substantial information on mainly published papers dealing with climatic change and variability in Canada during the last 2 million years. Where possible, author's abstracts have been used as annotations for they tend to state clearly not only the author's conclusions and priorities, but provide an idea of the general context of the work. Furthermore, perhaps use of these broader, deeper summaries (i.e. including more than specific paleoclimatic information) will allow this bibliography to be of greater use to scientists in other fields (Quaternary palynology, paleoecology, geology and glaciology come to mind because of the relative abundance of references to those fields in the index). In compiling the annotations we have tried to avoid too restrictive an approach to this broad and interesting subject: if we have erred, I hope it is on the generous side.

Besides using this bibliography as a specific research tool, it may be worthwhile for someone to review its contents in order to summarize the status of Quaternary paleoclimatic research in certain disciplines in various parts of Canada. A remarkable point noted by Anne Smithers is the relative abundance of references mentioning climatic change in the Canadian Arctic Islands ("Northwest Territories - Islands") - much of this work having stemmed from long-range, interdisciplinary studies on Baffin Island by research teams from the Institute of Arctic and Alpine Research (INSTAAR) at Boulder, Colorado, from similar projects of the Paleoecology and Geochronology Section, Terrain Sciences Division, Geological Survey of Canada, and of the Polar Continental Shelf Project. Similarly, surprisingly little paleoclimatic information is available for Saskatchewan. Also, it is obvious that evidence of past climates based on analysis of historic documents is lagging far behind contributions arising from palynological studies, for example.

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[1] Before Present ("present" being 1950).

Suggestions for improvement of this annotated bibliography are requested.

REFERENCE

Harington, C.R. 1980. The impact of changing climates on people in Canada; and the National Museum of Natural Sciences climatic change project. In: Climatic Change in Canada. Edited by: C.R. Harington. Syllogeus No. 26:5-15.

AVANT-PROPOS

C.R. Harington[1]

BUT

Depuis sa mise en oeuvre en 1977, le projet du Musée national des sciences naturelles concernant les changements climatiques a pour but fondamental de dresser une bibliographie exhaustive et annotée sur les paléoclimats du Quaternaire au Canada, en plus de faciliter la recherche dans ce domaine et de publier des données paléobiologiques, historiques et météorologiques importantes pour l'étude des changements climatiques survenus au Canada depuis la dernière glaciation il y a 20,000 ans (Harington 1980, p. 13). J'espère que cette bibliographie annotée (1) rappellera les sources et s'avérera un instrument de recherches utile aux professionnels; (2) apprendra aux profanes, aux étudiants et aux scientifiques encore à leurs premières armes où se renseigner sur les changements climatiques survenus au Canada depuis deux millions d'années (Quaternaire); (3) donnera une idée de la diversité des disciplines où des données paléoclimatiques ont été publiées et (4) montrera à quel point les recherches se sont accélérées dans ce domaine depuis quelques décennies, tout en indiquant les points forts et les lacunes de ces recherches en ce qui concerne la géographie, la géochronologie et la discipline elle-même.

Ce travail repose sur la conviction que la connaissance des climats anciens peut aider à mieux faire comprendre la nature, la chronologie et l'ampleur des changements climatiques futurs, pour peu que les données soient rassemblées et interprétées avec soin. Abstraction faite de leur valeur prévisionnelle, nous croyons que les résultats des études passées sur les changements climatiques du quaternaire au Canada, dont il n'est fait que sommairement état dans le présent ouvrage, s'avéreront utiles et intéressants pour les spécialistes (par exemple, les biogéographes, les paléoécologistes, les archéologues et les historiens).

HISTORIQUE

Cette bibliographie résulte en grande partie du travail effectué par deux étudiants au niveau de baccalauréat, Linda Ghanimé et Anne Smithers, qui ont travaillé à contrat sous ma supervision. Du 1er novembre au 31 mars 1979, Linda Ghanimé a compilé environ 500 annotations

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[1] Division de la paléobiologie, Musée national des sciences naturelles, Musées nationaux du Canada, Ottawa, Ontario K1A 0M8.

provenant surtout de Montréal (bibliothèques de l'université McGill - physique, météorologie, Blacker-Wood, botanique et génétique, McLennan; Bibliothèque du Centre for Northern Studies and Research; Collection du laboratoire de palynologie de l'Université de Montréal; Bibliothèque des sciences de l'Université du Québec à Montréal; et Bibliothèque des sciences et du génie de l'université Concordia). Avant son travail, je ne m'étais jamais rendu compte de la diversité et de l'abondance des sources, ni de l'ancienneté des publications dans certains cas.

Pour sa part, Anne Smithers a travaillé à la bibliographie du 1er septembre 1981 au 31 juillet 1982 puis du 1er janvier au 31 mars 1983. En plus de vérifier les annotations de Linda Ghanimé et de reformuler bon nombre des annotations antérieures, elle a considérablement augmenté et amélioré la bibliographie (portant le nombre total des annotations à 912): (1) en faisant se recouper les listes de références contenues dans les principaux documents pour voir si quelques sources n'avaient pas été omises; (2) en faisant des annotations des références pertinentes trouvées dans la liste informatisée du GEOREF pour 1961-1981 qui s'appliquait au sujet[1]; (3) en mettant les annotations à jour après avoir parcouru les récents numéros des revues scientifiques contenant des articles sur les paléoclimats du Quaternaire au Canada (p. ex. *Arctic, Arctic and Alpine Research; Canadian Journal of Earth Sciences; Climatic Change; Palaeogeography, Palaeoclimatology, Palaeoecology*); (4) en renumérotant les annotations finalement choisies et en dressant une liste des mots clés pour chacune; et (5) en préparant l'index final. Les principales sources d'information consultées par Anne Smithers se trouvent à Ottawa (p. ex. Musées nationaux du Canada, université Carleton, Commission géologique du Canada et bibliothèques d'Agriculture Canada). M.A. Stewart de la bibliothèque des Musées nationaux du Canada a eu l'amabilité de lui procurer les documents difficiles à obtenir en recourant au prêt entre bibliothèques.

De mon côté, j'étais chargé de planifier la bibliographie, de superviser le travail de nos collaborateurs à contrat, de choisir les annotations qui seraient incluses (les publications importantes contenant des références ont passé avant les résumés publiés et les documents inédits comme les thèses), de fournir quelques annotations, de dresser l'index (avec les précieux conseils des contractuels, Martha Andrews et C. Wilson) et d'apprêter le texte en fonction de la présentation requise pour un *Syllogeus*. Les dernières références du présent volume datent du début de 1983. Madame Gail Rice m'a aidé à préparer le texte et s'est bien acquittée des communications avec la Sussex Informatics, qui détenait le contrat de traitement du texte.

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[1] Les mots clés les plus utiles pour la recherche ont été: Canada (ou les noms des provinces et territoires), Quaternaire, Pléistocène, Holocène et paléoclimatologie.

ORGANISATION

Annotations

Les annotations sont énumérées par ordre alphabétique: nom de famille de l'auteur (ou du premier auteur) et date de publication. Chaque annotation est précédée d'un numéro qui facilite la consultation et qui rend plus succinct l'index à la fin du volume.

Les abréviations qui suivent les annotations indiquent leur source:

A.A. - Résumé de l'auteur.

A.B. - Résumé de la bibliographie de l'Arctique (Arctic Institute of North America).

A.B.S. - Résumé préparé par Anne B. Smithers.

A.C. - Conclusions de l'auteur.

A.I. - Introduction de l'auteur.

A.S. - Résumé de l'auteur.

A.S.C. - Résumé et conclusions de l'auteur.

C.R.H. - Résumé préparé par C.R. Harington.

D.A.I. - Résumé tiré de Dissertation Abstracts International.

Editor - Résumé du rédacteur.

Excerpt(s) - Résumé préparé à partir d'extraits pertinents du texte.

G.A. - Résumé tiré de Geo Abstracts.

L.G. - Résumé préparé par Linda Ghanimé.

P. - Résumé tiré de la préface.

p - La partie pertinente de l'ouvrage a été résumée (p. ex. pA.A. désigne la partie pertinente du résumé de l'auteur).

+ - Comprend d'autres informations pertinents (p. ex. une observation de l'annotateur donnée entre crochets).

Thomas - Résumé tiré de *Meteorological Studies of climatic fluctuations in Canada, 1917-1960. An annotated bibliography*, préparé par M.K. Thomas (1975).

Index

L'index est agencé par (1) **région géographique** - par ordre alphabétique des noms de provinces ou de territoires (les Territoires du Nord-Ouest sont divisés en deux catégories pour faciliter la consultation: "îles" et "continent"; voir carte, figure 1), "Canada - Généralités" (annotations faisant allusion à des régions canadiennes excédant les régions naturelles), "Amérique du Nord" (annotations faisant allusion au Canada et à d'autres parties de l'Amérique du Nord) et "monde" (annotations faisant allusion au Canada et à d'autres parties du mondes); (2) par **époque géologique** - "Quaternaire" (depuis environ 2 millions d'années), "Pléistocène" (d'il y a 2 millions d'années à environ 10,000 avant notre époque[1]), "Holocène - Préhistorique" (d'il y a 10,000 ans à 500 ans avant notre époque), "Holocène - Historique" (d'il y a 500 ans à notre époque) (figure 2); (3) par **sujets** - près de 40 noms de disciplines et de sujets sont énumérés par ordre alphabétique (après la catégorie "Généralités"). Certains sujets (p. ex. "climats" et "géologie") sont subdivisés pour permettre une consultation plus précise (table 1).

CONCLUSION

Nous avons cherché à établir une source d'information exhaustive sur les documents (surtout publiés) traitant des changements et des variations climatiques au Canada depuis deux millions d'années. Lorsque la chose était possible, les résumés d'auteur ont été considérés comme des annotations car d'habitude en plus d'énoncer clairement les conclusions et les priorités de l'auteur ils fournissent une idée du contexte général de l'ouvrage. De plus, peut-être ces résumés plus complets et plus approfondis (c.-à-d. contenant plus que des informations strictement paléoclimatiques) permettront-ils à la présente bibliographie d'être également utile aux scientifiques oeuvrant dans d'autres disciplines (palynologie du Quaternaire, paléoécologie, géologie et glaciologie sont des domaines auxquels l'index fait souvent allusion). En compilant les annotations nous nous sommes efforcés de ne pas être trop restrictifs; si nous nous sommes trompés, nous espérons en avoir mis trop plutôt que pas assez.

En plus d'utiliser cette bibliographie à des fins précises de recherche, quelqu'un aurait peut-être avantage à en revoir le contenu afin de résumer l'état des recherches sur les paléoclimats du Quaternaire dans diverses disciplines et dans diverses régions du Canada. Comme nous le fait remarquer Anne Smithers, nombreuses sont les références faisant allusion aux changements climatiques survenus dans les îles de l'Arctique (Territoires du Nord-Ouest - Iles"); beaucoup de ces documents sont le fruit des études interdisciplinaires à long terme effectuées sur la terre de Baffin par des équipes de l'Institute of Arctic and Alpine Research (INSTAAR) à Boulder (Colorado), de projets similaires réalisés par la Section de la paléoécologie et de la géochronologie, Division de la science des terrains, Commission géologique du Canada, ainsi que de l'Étude du plateau continental polaire. Inversement, on dispose de très peu d'information sur les paléoclimats de la Saskatchewan. Il est également évident que ce que les documents historiques révèlent sur les climats d'autrefois n'a pas du tout la même valeur que les conclusions auxquelles aboutissent les études palynologiques, par exemple.

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[1] Notre époque = 1950.

Nous accueillerons avec plaisir les améliorations qu'on voudra bien nous suggérer.

REFERENCE

Harington, C.R., 1980. The impact of changing climates on people in Canada; and the National Museum of Natural Sciences climatic change project. In: Climatic Change in Canada. Rédacteur: C.R. Harington. Syllogeus n^o 26:5-15.

ANNOTATIONS

1. **ALAM, M. 1976. Quaternary paleoclimates and sedimentation southwest of Grand Banks. Geological Association of Canada - Mineralogical Association of Canada, Joint Annual Meeting, Program and Abstracts 1:61.**

12-m long piston cores collected from the tops of seamounts southwest of the Grand Banks were examined for climatic signature and change in the sedimentation pattern. The cores consist of alternating clays and foram-nanno ooze. They were dated by C^{14}, paleomagnetism and foram and coccolith biostratigraphy. Foram and carbonate cycles were used for paleoclimatic determinations. They indicate that Eastern Canada was deglaciated three times during the last 600,000 years. Deglaciation occurred at 11,000 BP, 130,000 BP and 600,000 BP, which probably correspond to the classical Holocene, Sangamon and Yarmouthian Interglacials. In addition three interstadials occurred in the Wisconsin and two in the (?) Illinoian stage.

With the advance of continental ice, the Gulf Stream moved towards the southeast and the intensity of the Labrador Current increased. With the decrease of temperature, bottom current activity also increased. Biogenic productivity was greatly reduced and the faunal and floral assemblages changed. Eustatic sea level changes resulted in increased supply of shelf margin sediments to deep water and prevented Labrador Sea icebergs from crossing the Grand Banks. The provenance of the clays deposited during the glacial stages can be determined from their mineralogy. The (?) Early Illinoian sedimentation pattern was controlled by the advance of an ice sheet across Newfoundland. The Laurentian ice sheet eroded the Gulf of St. Lawrence in the (?) Late Illinoian. Sediment contribution from the Wisconsin ice sheet was relatively small and consequently it played a less important role in the sedimentation on the outer continental margin of Eastern Canada.

A.A.

2. **ALAM, M., and D.J.W. PIPER. 1977. Pre-Wisconsin stratigraphy and paleoclimates off Atlantic Canada, and its bearing on glaciation in Québec. Géographie physique et Quaternaire 31(1-2):15-22.**

Cores from tops of seamounts close to the continental shelf west of the Grand Banks contain sequences of alternating clays (representing glacials) and foram nanno ooze (deposited in warmer periods), back to the Pliocene. Although sedimentation in the cores is controlled primarily by glacial conditions on the Grand Banks and Laurentian Channel, glacial history further inland can be inferred. The Wisconsin sequence shows two cool interstadials and one rather warmer one, correlative with the Plum Point, Port Talbot and St. Pierre Interstadials. Clay sedimentation during Wisconsin glacial stages was minor, suggesting glaciers did not extend to the shelf edge. In the late Illinoian, there was a major influx of red sediments, indicating significant erosion of the Gulf of St. Lawrence and Laurentian Channel. Glaciation was more extensive than during the Wisconsin. Two Illinoian interstadials, with temperatures between those of the Plum Point and St. Pierre interstadials are recognized. Early Illinoian glaciation was the most severe yet recognized in the cores. Sedimentation appears to have been controlled by the advance of a Newfoundland - Labrador - E. Québec ice sheet across the Grand Banks.

A.A.

3. **ALEXANDER, M.E. 1978. Reconstructing the fire history of Pukaskwa National Park. In: Fire Ecology in Resource Management Workshop Proceedings, Dec. 6-7, 1977. Edited by: D.E. Dube. Canadian Forestry Service. Information Report NOR-X-210. pp. 4-11.**

Pukaskwa National Park comprises 186,000 ha and is located on the northeastern shore of Lake Superior. Periodic, random wildfires have influenced the vegetation patterns in the park. The Canadian Forestry Service and Parks Canada are conducting a joint investigation "to assess the historical, ecological, and managerial role of fire in Pukaskwa National Park"

(Alexander, 1977). This paper discusses the methodology (major techniques are dendrochronology, and written and oral accounts) and provides a progress report for the reconstruction of fire history.

"Preliminary results from a search of OMNR fire records revealed that since 1923, 55 fires have occurred (70% LC) with 14(13% LC) greater than 40 ha. Area burned by LC fires has been approximately 36,000 ha while MC area burned has amounted to less than 160 ha." Neither railroad building or logging activities appear to have increased fire occurrence. The author concludes with a review of some problems and future plans.

A.B.S.

4. **ALLARD, M. 1981. L'Anse aux Canards, Ile d'Orléans, Québec: évolution Holocène et dynamique actuelle. Géographie physique et Quaternaire 35(2):133-154.**

A tidal marsh 640 m wide and 1 km^2 in area was studied at Anse aux Canards near the downstream end of Orléans Island. The bay is opened to the northeast onto "le chenal de l'île d'Orléans" and the St. Lawrence middle estuary. A natural section in a stream bank provides a stratigraphic record of the tidal marsh evolution. At the bottom, a glacio-marine till dated 11,200 years BP may be correlated to a last glacial ice advance in the Goldthwait Sea following the topographic trend of the St. Lawrence River Valley. The next stratigraphic unit is made up of intertidal sands and gravels dated 1220 years BP. Overlying them are muds belonging to a tidal flat environment and including thin peat beds which have been dated from 790 to 1500 years BP. Pollen analysis of the peat reveals that regional vegetation at the time of deposition was characteristic of the Laurentian maple forest (*Aceretum sacchari*). Macro-remains analysis indicates a marsh vegetation identical to today's and typical of a fresh water tidal environment. The last stratigraphic surface unit consists of an intertidal marsh deposit. ...

pA.A.

5. **ALLARD, M., et G. TREMBLAY. 1981. Observations sur le Quaternaire de l'extrémite orientale de la péninsula de Gaspé, Québec. Géographie physique et Quaternaire 35(1):105-125.**

Three major types of glacial events have been identified over the Gaspé Peninsula, east of Rivière au Renard: 1) a radial ice-flow towards Baie de Gaspé and the Gulf of St. Lawrence coming from the Appalachian ridges. This ice-flow pattern is related to a local ice-cap and was identified from cirques in the hills, evidence of ice-flow in the valleys and the dispersion of erratics over the peninsula. 2) An important ice-flow in Baie de Gaspé which has been identified from glacial striations, till lithology and from the submarine topography of the bay. 3) A glacial influence of the Laurentide icesheet along the coast of the Gulf of St. Lawrence as evidenced by drift-ice striations and Precambrian clasts in glaciomarine deposits. This Laurentide ice influence is related to either a floating ice platform or to large icebergs. According to radiocarbon dates, deglaciation along the eastern Gaspé coast of the Gulf is synchronous with the deglaciation of the coast of the maritime estuary further west dated at about 13,400 - 13,600 years B.P. Evidence of a sea level at 30 m seems to mark the limit reached by the Goldthwait Sea in the study area. However, coastal erosion surfaces, raised notches in the cliffs and some sediments suggest that many fluctuations of the relative sea level occurred before glaciation and during the Quaternary. The most important Holocene geomorphological processes are mass movements, fluvial surges, lacustrine sedimentation and shoreline erosion and sedimentation.

A.A.

6. ALLEY, N.F. 1973. Glacial stratigraphy and the limits of the Rocky Mountain and Laurentide ice sheets in southwestern Alberta, Canada. Bulletin of the Canadian Petroleum Geologists 21(2):153-177.

The Quaternary deposits occurring in part of southwestern Alberta were investigated to determine the sequence of glacial events and the synchroneity and direction of movement of the Rocky Mountain and Laurentide ice masses. In this area there is evidence of three major glacial episodes of decreasing magnitude (an episode consisting of one Mountain and one Laurentide advance). During each episode, the Mountain glaciers reached their maxima and receded considerably before the advance of Laurentide ice. One other less extensive advance, subsequent to the last major glacial episode, occurred in the Mountains.

Tills deposited by advances of Mountain ice, named in order of decreasing age, are the Albertan, Maycroft, Ernst and Hidden Creek tills. In accordance with the stratigraphy of Stalker (1963) the Laurentide tills are referred to as the Labuma, Maunsell and Buffalo Lake tills. The Saskatchewan Sands and Gravels underlie the Albertan Till in the Foothills and the Labuma Till on the Plains.

Stratigraphic, radiocarbon and palynologic evidence suggests that the three major glacial advances are pre-Classical Wisconsin in age whereas the Hidden Creek advance is Classical Wisconsin.

A.A.

7. ALLEY, N.F. 1976. The palynology and paleoclimatic significance of a dated core of Holocene peat, Okanagan Valley, southern British Columbia. Canadian Journal of Earth Sciences 13(8):1131-1144.

Holocene vegetation and climatic changes of the Okanagan Valley, British Columbia, are inferred from fossil pollen assemblages recovered from Kelowna Bog in the central part of the valley. Broad climatic changes inferred from relict postglacial landforms in the valley are correlated with the above changes.

The Okanagan Valley was ice-free and Glacial Lake Penticton drained before 8900 yr BP. A forest consisting mainly of pine (*Pinus*) and stands of spruce (*Picea*) had colonized the valley sides prior to draining of the lake. Soon after 8400 yr BP, moist conditions gave way to aridity during which grass (Gramineae) and sagebrush (*Artemisia*) predominated. This warm, dry interval is correlated with the Hypsithermal. Bare areas in the valley bottom were exposed to wind erosion; sand dunes formed in some areas, whereas in others, a veneer of aeolian sediment was laid down. At approximately 6600 yr BP, the climate became cooler and moister, aeolian activity diminished, and the dunes became stabilized by vegetation. During the ensuing latest climatic interval, three moister phases affected the Kelowna Bog and were characterized by large increases in birch (*Betula*), alder (*Alnus*), and hazel (*Corylus*). These phases, which were related to increased runoff from the adjacent uplands, are tentatively correlated with the stades of the Neoglaciation recognized in southcentral British Columbia and neighbouring United States.

A.A.

8. ALLEY, N.F. 1979. Middle Wisconsin stratigraphy and climatic reconstruction, southern Vancouver Island, British Columbia. Quaternary Research 11(2):213-237.

Interbedded, organic-rich terrestrial and marine sediments exposed along the eastern coastal lowland of Vancouver Island contain an almost continuous record of middle Wisconsin vegetation and climate. The record has been interpreted largely from palynostratigraphic studies at three sites and supported by a study of modern pollen spectra from the three major biogeoclimatic zones of the extant vegetation. Radiocarbon dates from a variety of organic materials in the middle Wisconsin beds reveal that the fossil pollen spectra span an interval ranging from approximately 21,000 yr B.P. to more than 51,000 yr B.P. The spectra are divided into eight major pollen zones encompassing the Olympia Interglaciation and early

Fraser Glaciation geologic-climate units of the Pacific Northwest. The Olympia Interglaciation extended from before 51,000 yr B.P. to ca. 29,000 yr B.P. and was characterized by a climate similar to present. During the early Fraser Glaciation, from 29,000 years ago to approximately 21,000 yr B.P., climate deteriorated until tundra-like conditions prevailed. These pollen sequences are correlative with those of coastal British Columbia and partly with those from Olympic Peninsula, but apparently are not comparable with events in the Puget Lowland.

A.A.

9. **ALLEY, N.F., and S.C. CHATWIN. 1979. Late Pleistocene history and geomorphology, southwestern Vancouver Island, British Columbia. Canadian Journal of Earth Sciences 16(9):1645-1657.**

The major Pleistocene deposits and landforms on southwestern Vancouver Island are the result of the Late Wisconsin (Fraser) Glaciation. Cordilleran glaciers formed in the Vancouver Island Mountains and in the Coast Mountains had advanced down Strait of Georgia to southeastern Vancouver Island after 19000 years BP. The ice split into the Puget and Juan de Fuca lobes, the latter damming small lakes along the southwestern coastal slope of the island. During the maximum of the glaciation (Vashon Stade), southern Vancouver Island lay completely under the cover of an ice-sheet which flowed in a south-southwesterly direction across Juan de Fuca Strait, eventually terminating on the edge of the continental shelf. Deglaciation was by downwasting during which ice thinned into major valleys and the strait. Most upland areas were free of ice down to an elevation of 400 m by before 13000 years BP. A possible glacier standstill and (or) resurgence occurred along Juan de Fuca Strait and in some interior upland valleys before deglaciation was complete. Glacial lakes occupied major valleys during later stages of deglaciation.

A.A.

10. **ALLIS, R.G. 1978. The effect of Pleistocene climatic variations on the geothermal regime in Ontario; a reassessment. Canadian Journal of Earth Sciences 15(11):1875-1879.**

A revised glaciation chronology for Ontario that spans the last half million years is derived by combining recent results from oxygen isotope analysis in deep sea cores with evidence from studies of the Pleistocene geology of the province. The chronology suggests that the perturbation to the geothermal gradient may be up to 50% larger than previously thought in central parts of Ontario.

A.A.

11. **ALLIS, R.G. 1979. The effect of Pleistocene climatic variations on the geothermal regime in Ontario; a reassessment; reply. Canadian Journal of Earth Sciences 16(7):1517.**

Allis replies to the discussion of his 1978 article by Beck (1979). The author clarifies the use of his two-step model.

A.B.S.

12. **AMOS, C.L. 1978. The post glacial evolution of the Minas Basin, N.S. A sedimentological interpretation. Journal of Sedimentary Petrology 48(3):965-982.**

Geophysical and vibrocore information was used to interpret the distribution, character and evolution of post-glacial sediments in the Minas Basin, Bay of Fundy. Sedimentological evidence provided information on the environment of deposition of the sediments found. Results show that the Minas Basin seabed has not been subaerially exposed since glacial times and that deposition has taken place under continuously marine conditions. During the approximate period 8,600 years B.P. - 6,300 years B.P. the Minas Basin was non-tidal and sedimentation occurred predominantly in the deeper parts of the embayment. From 6300 years B.P. to the present, tidal activity has been increasing linearly; the present tidal activity is the most energetic condition to have occurred in the system. During this period deposition was progressively more predominant in the marginal regions, developing the sandflats, mudflats and salt marshes visible today. The progressive inundation of the Minas Basin margins is a function of an increase in tidal range (50%) and a rise in apparent mean sea-level (50%).

A.A.

13. ANDERSON, J.H. 1970. Holocene environments in the Atlin Valley, northwestern British Columbia, as determined by palynology. Geological Society of America, Abstracts 2(6):373.

Pollen and spore percentage frequency diagrams for five bogs in the Atlin Valley were dated by the radiocarbon method and divided into assemblage zones as follows: 1. Willow-alder-*Dryas-Artemisia*, 10,500 - 8,500 years BP; 2. Alder-birch-sedge, 8,500 - 5,800 years BP; 3. Spruce-alder-*Pediastrum*, 5,800 - 4,000 years BP; 4. Spruce-fir-sedge, 4,000 - 1,200 years BP; 5. Pine, 1,200 years BP to Present. Each zone also contains a number of diagnostic minor types.

The assemblage of zone 1 is interpreted as representing a shrub tundra vegetation on valley walls and early successional vegetation on proglacial terrain under relatively cold and humid climatic conditions. Zone 2 represents a transitional forest tundra on valley walls and an advanced stage of succession on the valley floor where forest was also developing. The climate associated with this zone may have been cool and relatively dry. Zone 3 represents maximum and wide-spread development of climax white spruce forest under optimum climatic conditions, interpreted as relatively warm and humid. Zone 4 reflects a still widespread forest vegetation, but with some changes in proportions of important species. A slight drop in temperatures and a decrease in precipitation is indicated. Zone 5 represents the modern vegetation of the Atlin Valley. The associated climatic conditions are defined as relatively cool and dry. The Thermal Maximum in the Atlin Valley is believed to have begun early in zone 2 times and to have ended about mid-way through zone 4.

The sequence of Holocene environmental changes seen here is similar to, but not in phase with sequences developed in other regions.

A.A.

14. ANDERSON, T.W. 1980. Holocene vegetation and climatic history of Prince Edward Island, Canada. Canadian Journal of Earth Sciences 17(9):1152-1165.

The vegetation and climate of the Holocene of Prince Edward Island are reconstructed from pollen analysis of four *Sphagnum* peat bogs, Portage and East Bideford Bogs in the west and Mermaid and East Baltic Bogs in the east. The discussion is based largely on percentage data supported by pollen influx estimates.

The earliest recognizable vegetation was tundra-like with non-arboreal birch, willow, *Artemisia*, and upland grasses and sedges. The vegetation changed remarkably within a short period, from tundra at 10,000 years BP, to forest-tundra (spruce-non-arboreal birch association) between 10,000 and 8000 years ago, to pine at or shortly after 8000 years ago. Hemlock arrived 7000 years ago and dominated along with white pine from about 6500-4500 years BP. Beech came in about 3400 years ago and formed part of a hemlock-beech-birch association up until modern times. Sharp increases in weeds and grasses and declines in hemlock, birch, and beech denote European settlement approximately 100-150 years ago.

A gradual warming trend is inferred for the period prior to about 8000 years BP, but rapid climatic improvement took place shortly after 8000 years ago corresponding with the pollen transition from spruce to pine. Maximum temperatures (close to 8.5°C) were reached approximately 4000 years ago when the mean annual temperature may have been almost 2.5°C warmer than present. Deterioration of the climate occurred at approximately 3000 and 1500 years ago, coinciding with increases in spruce, Ericaceae, and *Sphagnum*, and a decrease in pine.

A.A.

15. **ANDERSON, T.W., and J. TERASMAE. 1966. Palynological study of bottom sediments in Georgian Bay, Lake Huron. Great Lakes Research Division, University of Michigan Publication 15:164-168.**

A series of surface samples of bottom sediment from precisely located stations has been collected and examined for pollen and spores from central Georgian Bay. The assemblages obtained show a relationship to the surrounding regional vegetation and are different from those obtained from lakes and bogs north and south of Georgian Bay in the boreal and deciduous forest regions, respectively...

The dominant pollen types identified in the surface samples are pine, maple, oak and elm. Among the non-tree pollen, Chenopodiaceae, *Ambrosia* (ragweed), and *Artemisia* are the most frequent, whereas fern spores and *Lycopodium* (club-moss) spores are present in most samples.

The consistent presence and more particularly the abundance of pollen identified as that of maple (*Acer*) has puzzled the writers throughout this study. None of the surface samples studied so far in areas east and north of Georgian Bay has shown such abundance of maple pollen. ...The following possible explanation is suggested for the abundance of maple pollen in the Georgian Bay assemblages. Warm and sunny weather conditions in the Georgian Bay area are associated with southwesterly and southerly winds at the time of flowering and dispersal of maple pollen. Easterly winds commonly bring cool weather and precipitation. Northwesterly and northerly winds are commonly associated with cool and sunny weather and local conditions (microclimate) may be suitable for flowering of maple. It seems conceivable that this abundance of maple pollen in the Georgian Bay bottom samples is related to specific weather conditions which obtain at the time of maple flowering.

A.A.$^+$

16. **ANDREWS, J.T. 1961. The development of scree slopes in the English Lake District and central Quebec-Labrador. Cahiers de géographie de Québec 5(10):219-230.**

Compares results of talus slope measurements at Wasdale in England with such near Schefferville during the summers of 1958 and 1959. The topographic, lithologic, and soil features of these slopes are examined, and the morphologic and climatic factors in their genesis considered, with conclusion that the talus slope is a possible indicator of a change of climate, affecting the supply of material to that slope. Question of a post-glacial climate colder than the present however, is not answered by these results.

A.B.

17. **ANDREWS, J.T. 1972. Recent and fossil growth rates of marine bivalves in Canadian Arctic and Late-Quaternary Arctic marine environments. Palaeogeography, Palaeoclimatology, Palaeoecology 11(3):157-176.**

Growth rates of three marine bivalves - *Mytilus edulis*, *Serripes groenlandicum* and *Clinocardium ciliatum* - are used to elucidate Late-Quaternary marine conditions in the Canadian Arctic and Subarctic. Present-day growth rates in Subarctic waters are statistically faster than those for the same species in Arctic waters. Fossil growth rates are analysed for a 6,000- and 8,500-year sequence from central Hudson Bay and east Baffin Island. These data suggest that growth rates and the size of coexistent clams, *Mya truncata* and *Mya pseudoarenaria*, increased to a maximum about 3,500 BP and have since declined. Growth rates did not increase to Subarctic values and hence the increase is related to temperature and salinity changes of the surface layer rather than by vertical mixing with the Atlantic water layer at depth. During the period 8,000 - 2,500 BP *M. edulis* and *Macoma balthica* extended up to the east coast of Baffin Island and across the entire Arctic mainland coast; *Chlamys islandicus* does not appear to have been as widespread. In the last 2,500 years or so these species have retreated to the west and south.

A comparison of raised, Late-Quaternary marine deposits throughout the North-Atlantic Arctic indicates similar biostratigraphic zones. Warmer conditions than today prevailed between 8,500 and 2,500 B.P. with an optimum $\sim$ 3,500 B.P. These dates suggest that marine conditions lagged behind terrestrial climatic changes, thus superimposing (in time) a cool atmosphere/warm ocean system that might explain the renewed glacierization of Arctic regions in the Neoglacial.

A.A.

18. ANDREWS, J.T. 1973. The Wisconsin Laurentide ice sheet: dispersal centers, problems of rates of retreat, and climatic implications. Arctic and Alpine Research 5(3):185-199.

Isochrone maps on the late Wisconsin deglaciation of the Laurentide ice sheet enable estimates to be made of changes in the volume and area of the ice sheet. The average marginal recession between 12,000 and 7,000 BP is estimated as 260 m yr^{-1} and varies little between the northwest and southern margins. The northeastern margin retreated at 20 m yr^{-1} and the overall tendency was for the Laurentide ice sheet to migrate toward Baffin Island. Vertical mass loss required to produce marginal retreat of over 200 m yr^{-1} indicates values between 10 and 50 m of vertical ice wastage per year. Consideration of atmospheric energy sources provides approximate ablation season inputs of 60, 14, and 6 Kcal. cm^{-2}/yr^{-1} for the south, northwest, and northeast margins compared to required totals of 72 to 360, 72 to 360, and 8 to 16 Kcal. cm^{-2}/yr^{-1}, a deficiency in the energy sources by a factor of between 1 and 17.

Attention is directed to the great extent of lacustrine and marine environments during deglaciation so that extensive sectors of the Laurentide ice sheet terminated in water; calving is considered the most likely additional ablation process that would explain both the high rates of marginal retreat and the lack of difference in retreat rates of margins at 72°N and 45°N.

Large end moraines are commonly interpreted as the response of an ice sheet to climatic change; however, the ice sheet responds to climate through the associated mass balance fluctuations. Major end moraines within the borders of the Laurentide ice sheet are frequently preserved immediately above the local marine limit or glacial lake level, suggesting that moraines may be caused by a lag in response of the ice sheet to the reduction in frontal calving, thus resulting in a limited readvance or stillstand. Such moraines are not associated with climatic change.

A.A.

19. ANDREWS, J.T. 1973. Late Quaternary variations in oxygen and carbon isotopic compositions in Canadian Arctic marine bivalves. Palaeogeography, Palaeoclimatology, Palaeoecology 14(3):187-192.

The oxygen and carbon isotopic composition of arctic marine bivalves *Mya truncata, Hiatella arctica*, and *Mytilus edulis* are reported on samples from raised marine deposits in Hudson Bay and Baffin Island. The shells range in age from modern, through the Holocene, to "old" marine units. During the Holocene the $^{18}O/^{16}O$ ratio in shells rose to a maximum about 3500 BP which coincides in time with the period of maximum growth rates of bivalves, maximum size and maximum faunal diversity. The change is interpreted to indicate that about 3500 years ago arctic waters may have reached a salinity ~1-2% greater than present. Comparison of Holocene shell-carbonate isotopic compositions with those from the "old" marine shells (that are characteristically extremely thick) suggests that during the early Wisconsin advance on eastern Baffin Island, surface and near-surface waters were more saline than at present. This may have been related to low meltwater discharge. Paradoxically, positive values of $^{18}O/^{16}O$ and $^{13}O/^{12}O$ in marine shells occurred during the Holocene marine optimum and during the early Wisconsin ice advance.

A.A.

20. ANDREWS, J.T. 1978. Quantitative Holocene climatic parameters derived from pollen records in the eastern Canadian Arctic. American Quaternary Association, National Conference, Abstracts 5:156.

Transfer function equations have been developed for the prediction of: January temperatures, July temperatures, summer precipitation, and Young's index of summer warmth. The equations are based on a transect of moss polster data running from Fort Chimo in Nouveau-Québec to Clyde River, Baffin Island (ca 59 to 71°N). The modern data run from near treeline northward through Low Arctic shrub tundra into High Arctic tundra. Statistically the equations explain 80% or more of the variance in the modern data, and are based on five factors (assemblages). These equations have been applied to a series of pollen profiles from peats and organic-poor sediments from Cumberland Peninsula, Baffin Island (ca 66°33'N) that date variously between 7000 BP and the present date. Three profiles have records that start at 2500 BP and estimated climatic parameters allow some test of the reproducibility of the trends developed from the transfer function reconstructions. Results indicate that July temperatures were about 1° higher 7000 to 5000 years ago than they were between about 2500 to 650 BP. Present temperatures (probably averaged over the last 30 to 50 years) are similar to those that prevailed during the local thermal optimum on Baffin Island. Detailed pollen profiles covering sections of the last 2500 years (Nichols 1975; Boulton et al., 1976) indicate several periods of "warm/wet" summer weather although the prevailing neoglacial climate appears to have been "cold and dry".

A.A.

21. ANDREWS, J.T., and D.M. BARNETT. 1979. Holocene (Neoglacial) moraine and proglacial lake chronology, Barnes Ice Cap, Canada. Boreas 8(3):341-358.

Lichen diameters and radiocarbon dates from the western and southern margins of the Barnes Ice Cap yield a growth curve similar to that from southeastern Baffin Island. As a consequence, the moraine chronology of the northern and western Barnes Ice Cap needs revision, as does the chronology of the large proglacial lakes that existed north of the present Barnes Ice Cap. The revised chronolgy indicates that moraines were formed along the western margin of the Barnes Ice Cap during the following intervals: (1) less than 100 years ago; (2) 400-500 B.P.; (3) ca. 750 B.P.; (4) ca. 1000 B.P.; (5) ca. 1600 B.P.; (6) ca. 2100 B.P.; and (7) 2800 to 3100 B.P. As the western margin of the Barnes Ice Cap retreated, punctuated by stillstands and readvances, the northern margin of the Barnes Ice Cap lay athwart a series of westerly draining valleys, and a complex of proglacial lakes were dammed between the ice margin and the height of land. This sequence is traced by means of well-developed shorelines, lacustrine deltas, and spillways; specific lake levels are dated by lichenometry.

The Barnes Ice Cap moraine sequence is more complex than other Neoglacial records fringing mountain glaciers in Colorado, Alaska and Lappland. However, the chronology for the western Barnes Ice Cap closely resembles independent moraine chronology of mountain glaciers in Cumberland Peninsula, Baffin Island, and thus indicates that the difference between the Baffin Island climatic record and the general Neoglacial/Holocene climatic record (Denton and Karlén, 1977) is real. Comparison of specific data from Swedish Lappland and Baffin Island shows substantial agreement. Although Neoglacial records may be globally synchronous, the case for a 2500 year periodicity of glacial fluctuations is not proven: a 300 to 600 year return interval is suggested for the period between 0 and 3000 B.P.

A.A.

22. **ANDREWS, J.T., and R.G. BARRY. 1972. Present and paleoclimatic influences on the glacierization and deglacierization of Cumberland Peninsula, Baffin Island, N.W.T., Canada. University of Colorado Institute of Arctic and Alpine Research, Occasional Paper 2:1-215.**

The purpose of the research discussed in this report was to attempt an integrated analysis of the past and present climates of the northern Cumberland Peninsula region with specific attention focussed on the links between glacier distribution and fluctuations and the climate. The final objective of the research is to attempt to model the paleoclimate of the region during the late Quaternary.

pA.I.

23. **ANDREWS, J.T., R.G. BARRY, R.S. BRADLEY, G.H. MILLER, and L.D. WILLIAMS. 1972. Past and present glaciological responses to climate in eastern Baffin Island. Quaternary Research 2(3):303-314.**

Much of Baffin Island is close to the modern glaciation limit and climatic changes within the last decade are already being reflected in snow cover extent. Statistical analysis of glacierized and ice-free corries indicates that changes in direct solar radiation due to astronomical factors are inadequate to account for glacierization of those at present ice-free. These and other sources of evidence demonstrate the need for augmented winter snowfall in order to increase the extent of glacierization. The pattern of glacial history in this area is for maximum ice extent during the early glacial phase (>68,000, <137,000 BP), followed by a reduction in ice volume during the cold pleniglacial (>24,000, <68,000 BP) and then a limited late glacial advance (the Cockburn Stade, ca. 8,000 BP) due to increased precipitation. The Barnes Ice Cap did not disappear in the Holocene as it did in the last interglacial. The area is highly suitable for long-term monitoring of climatic change and glacial response.

A.A.

24. **ANDREWS, J.T., R.G. BARRY, P.T. DAVIS, A.S. DYKE, M. MAHAFFY, L.D. WILLIAMS, C. WRIGHT, and D.A. DAVIES. 1975. The Laurentide ice sheet: problems of the mode and speed of inception. In: Long-term Climatic Fluctuations. World Meteorological Organization, Geneva, WMO-421, pp. 87-94.**

The growth rate and development of the Laurentide ice sheet are briefly described followed by a discussion of the extent of the late Neoglacial snow cover over northern Baffin Island as an example of an 'abortive' glaciation. The use of a three-dimensional numerical ice flow model to conduct an experiment on the growth rate of the Laurentide ice sheet is also described.

G.A.

25. **ANDREWS, J.T., R.G. BARRY, and L. DRAPIER. 1970. An inventory of the present and past glacierization of Home Bay and Okoa Bay, east Baffin Island, N.W.T., Canada, and some climatic and paleoclimatic considerations. Journal of Glaciology 9(57):337-362.**

An air-photograph inventory of the present glacierization of areas of east Baffin Island adjoining Home Bay and Okoa Bay is described. Ice fields characterize the broad mountain summits of the former, while the latter is an area of cirque glaciers. The extent of glacierization is statistically related to various topographic parameters. It is found that there is a 4:1 ratio between Home Bay and Okoa Bay in the area of ice as a percent of the land area above 600 m a.s.l. Trend-surface analyses are made of the distribution of snowbanks and of cirques (empty and with ice bodies) in the two areas. The orientation of the cirques and of the ice-field glaciers in Home Bay is also examined. 39% of empty cirques in Okoa Bay face south, whereas those with existing glaciers are restricted to orientations with azimuths between 310° - 145°. Neither glacier length nor the observable recession in the Home Bay area show any significant difference with regard to aspect.

Consideration of climatic parameters (snowfall and degree days) and synoptic-climatological results provide no reason for the strong contrast between the two areas. Cool, cloudy summer conditions are associated with easterly flow components that should affect both areas. A possible model for the inception of the mountain ice fields of Home Bay c. 2000-4000 years ago is outlined and it is suggested that differential lag effects between the ice bodies in the two areas may be responsible for some of the observed difference. The many parodoxical relationships between glacierization, topography and climate in these areas, and the rather negative results, emphasize the dangers of facile paleoclimatic interpretations.

A.A.

26. **ANDREWS, J.T., J.T. BUCKLEY, and J.H. ENGLAND. 1970. Late-glacial chronology and glacio-isostatic recovery, Home Bay east Baffin Island, Canada. Geological Society of America Bulletin 81:1123-1148.**

Fossiliferous raised marine deposits occur around Home Bay, east Baffin Island, Northwest Territories. We have developed a late-glacial chronology on the bases of 32 radiocarbon dates and morphostratigraphic evidence. In addition, the similarity of observed and predicted postglacial emergence curves enabled development of techniques that provided age estimates of marine limits throughout the area, and allowed construction of an isochron map for deglaciation.

Retreat of the fiord glaciers was relatively rapid (average 27 m yr^{-1}) between 10,000 and about 8000 BP. Evidence for a major readvance of the glaciers about 8000 years ago includes moraines overlying marine clay, elevation of associated raised delta deposits relative to local marine limits, and a prominent and extensive moraine, the Ekalugad Moraine (new name). Related radiocarbon dates are similar in age to the Cockburn Moraine of Arctic Canada. Another moraine, dated about 6800 BP, is of similar age to the Isortoq Moraine of west Baffin Island. Valley glaciers from the main interior ice sheets were still descending to near sea level only 4500 to 4000 years ago. Disappearance of the interior ice sheet west of Home Bay apparently coincided with, or at least preceded, the growth of the local mountain ice caps.

Marine limit elevations are a function of distance from the continental shelf (a measure of ice thickness) and date of deglaciation; elevations, consequently, incline inland to the outer limit of the Ekalugad Moraine (from 40 m to a maximum of 91 m) and then decline inland, thus reflecting the slow deglaciation and the importance of restrained rebound. Isobases are oriented from 140° to 320°. Glacio-isostatic recovery has led to the warping of former marine planes. Maximum tilt on the oldest strandline (8600 years old) is 1.8 m km^{-1}.

A.A.

27. **ANDREWS, J.T., P.T. DAVIS, L. GLASSGOLD, and H. NICHOLS. 1979. Late Holocene July temperatures from Ennadai Lake (Keewatin) and Windy Lake (Baffin Island), Arctic Canada, based on transfer function equations on fossil peats. Geological Society of America, Abstracts with Programs 11(7):379-380.**

Transfer functions have been developed for two transects. The first trends N-S from treeline in Labrador to 71°N on Baffin Island. The second trends SW-NE from within the Boreal Forest in Keewatin across the Barren Grounds to Baffin Island. Present climatic parameters are statistically well explained by only a few taxa. July temperatures (°C) have r^2 values of 0.83 and 0.91 based on 6 and 4 taxa respectively. The N-S transect equation includes:

Alnus, Gramineae, *Picea*, *Salix*, Ericaceae and *Betula*, whereas the SW-NE transect includes: *Picea*, *Alnus*, *Betula* and Gramineae. The Windy site dates between 650 and 3600 BP. Sedimentation rate was uniform throughout and the sampling interval is ca. 35 yr. The Ennadai diagram covers the period 4700 to ca. 650 BP. Sedimentation rates were not uniform; we have averaged temperatures over 100 yr intervals. The results from Windy and Ennadai Lakes confirm a "step" drop in July T°C between 2700 and 2500 yrs BP with temperatures falling 2 to 3°C and never fully recovering during the last 3000 years except during the recent "little climatic optimum".

Windy L.	(July T°C)	Ennadai L.	(July T°C)
		4.6 - 3.8	10.5 P
3.5	8.8 P	3.6 - 3.3	9.5 T
3.4 - 3.2	6.1 T	3.3 - 2.8	10.2 P
3.0 - 2.6	8.0 P	2.7	8.0 T
2.5	6.3 T	2.1 - 1.9	7.5 T
2.1	5.4 T	1.5	9.0 P
1.5	6.6 P	1.2	7.7 T
.6 x 10^3BP	5.8 T	1.0 x 10^3BP	9.0 P

P = Peak
T = Trough

A.A.

28. ANDREWS, J.T., P.T. DAVIS, W.N. MODE, H. NICHOLS, and S.K. SHORT. 1981. Relative departures in July temperatures in northern Canada for the past 6,000 yr. Nature 289(5794):164-167.

There has been concern about recent temperature trends and the future effects of CO_2 concentrations in the atmosphere; but instrumental records only cover a few decades to a few centuries and it is essential that proxy data sources, such as pollen spectra from peats and lake sediments, be carefully interpreted as climate records. Several workers have shown statistically significant associations between the modern pollen rain and climatic parameters, an approach that by-passes the recognition of pollen/vegetation units. Statistically defined equations that associate abiotic and biotic elements are called transfer functions. We report here on the application of transfer function equations to nine middle and late Holocene peat and lake sediment sequences from northern Canada.

Between 5,500 and 6,000 years ago, in northern Canada, mean July temperature departures were, on average, negative. July temperature departures then rose to above average values until 2,500 yr BP, with a reversal between 5,000 and 4,500 yr BP. The highest average departures from July conditions occurred 3,500-4,000 yr BP, which apparently represents a Holocene local thermal optimum for the eastern and central Canadian Arctic. Between 3,000-2,500 and 1,000-500 yr BP, the average departures declined steadily and reached a trough in the latter interval.

A.A.+

29. ANDREWS, J.T., P.T. DAVIS, and C. WRIGHT. 1976. Little Ice Age permanent snowcover in the eastern Canadian Arctic: Extent mapped from Landsat-1 satellite imagery. Geografiska Annaler 58A(1-2):71-81.

Extensive areas of the eastern Canadian Arctic are light grey/white on both conventional black and white air photography and on multi-spectral LANDSAT-1 satellite imagery. These areas stand out in marked contrast to the darker toned surrounding terrain. Field investigations indicate that the light grey areas possess few lichens or plants; in contrast, their margins abut terrain with a mature lichen cover. Areas within the lichen trimlines are interpreted as the sites of former permanent snowbeds and snowfields. Radiometric and lichenometric dates indicate that the episode of permanent snowfields occurred about 500 to 300 years ago with retreat starting between 300 and 70 years ago. The LANDSAT-1 satellite imagery at a scale of 1:1 000 000 has proven ideal for mapping the regional extent of this former snowcover and this is illustrated by two frames from northcentral Baffin Island. Interpretation problems can arise from a number of sources, such as: light early summer or fall snowcover, limestone bedrock, recent outwash plains, and low clouds. However, ambiguities can be eliminated by inspection of LANDSAT-1 frames from different passes, by the examination of 1:60 000 air photographs, by the use of 1:250 000 scale contour maps, and by comparison with maps of the bedrock geology.

A comparison of Little Ice Age glaciation levels with those based on the present distribution of permanent ice/snow bodies indicates that during the Little Ice Age the regional snowline fell between 100 and 400 m; thus extensive areas of the upland plateaus of Baffin Island above 600 m were mantled by a thin but extensive permanent snowcover. This study serves to provide a realistic model for the inception of a North American ice sheet.

A.A.

30. **ANDREWS, J.T., and H.F. DIAZ. 1981. Eigenvector analysis of reconstructed Holocene July temperature departures over northern Canada. Quaternary Research 16(4):373-389.**

July temperatures for the past 6000 yr at 11 sites in northern Canada have been predicted by transfer-function equations. Normalized departures from the means of each time series at 250-yr intervals are analyzed by principal component (eigenvector) analysis. An initial analysis included 9 sites and the first three principal components accounted for 85.7% of the variance. Maps of the loadings on the principal components show broad spatial coherence on all three components. Temporal coefficients (principal component scores) illustrate major regional and local midsummer temperature variations. An additional 2 sites were then included but the spatial pattern of the loadings remained essentially unchanged. A further test of this approach, with a view toward predicting paleoclimates of northern regions, was to use the spatial coefficients (loadings) to estimate the July temperature departures at an "unknown" site (Long Lake, Keewatin). This reconstruction compares favorably with an independent transfer-function reconstruction (Kay, 1979). Power spectrum analysis of the significant principal component scores (temperature departures) over the 6000 yr showed that the temporal fluctuations associated with the first three principal components follow a "red noise" spectrum, indicative of strong persistence in the reconstructed climatic records. The scores on the fourth principal component approximated a "white noise" spectrum. A peak in power between 2000 and 3000 yr occurs in the variance spectrum of the second principal component (significance 10%). We conclude that eigenvector analysis of Holocene paleoclimatic data has considerable power and may be useful for identifying regional and local climatic variations.

A.A.

31. **ANDREWS, J.T., and R.E. DUGDALE. 1971. Quaternary history of northern Cumberland Peninsula, Baffin Island, N.W.T.: Part V: Factors affecting corrie glacierization in Okoa Bay. Quaternary Research 1(4):532-551.**

Corries in Okoa Bay contain glaciers, ice patches or are empty. Each of 165 corries is described by 17 variables that describe shape, location and geometry and also have some relationship to the glaciological conditions in each basin. Analyses of these data in terms of "explaining" the factors controlling glacierization (using information and graph-theoretic methods and multiple stepwise discriminant analysis) all emphasize the importance of elevation on the current pattern. Orientation is also significant as virtually all glaciers and ice patches are contained in north-facing corries. Residual elevations from a linear trend surface on corrie lip altitudes indicate that empty corries lie, on average, only 200 m below those currently ice-filled, thus the area is extremely sensitive to the effects of climatic change. Empty corries also lie at the same elevations, on average, in north and south-facing locations. The orientation of glacierized corries towards the north is a reflection of the variations in insolation between north- and south-facing slopes at latitude 67°30'N. Calculations indicate a difference under clear skies of 25% for global radiation and ~50% for absorbed short-wave radiation. The 200 m lowering of local snowline implied by the corrie lip data is equivalent to a 1.2°C temperature decrease - this is the same as estimates based on changes in the earth's orbital parameters for this latitude. A lowering of temperature results in an increase in the ratio: sublimation/melting which leads to a reduction in the amount of ablation. It is suggested that glacierization of much of Baffin Island is possible with a lowering of snowline by 200 m, this could then trigger other areas such as Labrador and Keewatin.

A.A.

32. ANDREWS, J.T., and G. Falconer. 1969. Late glacial and postglacial history and emergence of the Ottawa Islands, Hudson Bay, Northwest Territories: Evidence on the deglaciation of Hudson Bay. Canadian Journal of Earth Sciences 6(5):1263-1276.

The Ottawa Islands are in the northeastern part of Hudson Bay. Evidence from crossing striations suggests that the earliest recorded glacial movement was toward the northeast. With deglaciation of Hudson Strait and central Hudson Bay the ice movement shifted progressively in an anti-clockwise direction, with the final movement being toward the west-southwest. The islands were deglaciated between 7610 and 7250 radiocarbon years ago. The marine limit is 158 m above sea level. Deltaic deposits below the marine limit are grouped into sets that correlate with glacial advances in Labrador-Ungava and Baffin Island, and with palynological results from Keewatin, suggesting that they reflect climatically induced processes rather than a balance in eustatic-isostatic movements. Radiocarbon dates on marine molluscs enable postglacial uplift and emergence curves to be drawn, which agree closely with predicted curves.

Rates of uplift were about 0.06 m yr^{-1} at 6500 yr B.P., whereas the present rate is about 0.008 m yr^{-1}. The deglaciation of Hudson Bay was marked by the splitting of the ice sheet along the submarine deep that trends southward between Mansel and Coats islands toward the southwest coast of the bay.

A.A.

33. ANDREWS, J.T., and J.D. IVES. 1972. Late- and postglacial events (<10,000 B.P.) in the eastern Canadian Arctic with particular reference to the Cockburn moraines and breakup of the Laurentide Ice Sheet. In: Climatic Changes in Artic Areas During the Last Ten-thousand Years. Edited by: Y. Vasari, H. Hyvärinen and S. Hicks. Acta Universitatis Ouluensis Series A, Scientiae Rerum Naturalium 3, Geologica 1:149-174.

The Cockburn Moraines (morpho-stratigraphic term) of the Canadian Arctic are discussed in terms of their climatic implications at two levels: the first is their place in the late-glacial chronology of eastern Baffin Island, N.W.T.; the second is their relationship on the regional scale to the final disintegration of the Laurentide Ice Sheet and the Cochrane readvance, south of James Bay. In eastern Baffin Island an analysis of 144 radiocarbon dates from coastal sites indicates a marked peak in the number of dates between 8,500 and 7,500 B.P. and a complete absence of any dates between 10,500 and 24,000 B.P. It is now certain that several areas on the outermost coast of eastern Baffin Island were not covered by late-Wisconsin fiord glaciers, so that the absence of ^{14}C dates in this interval is unusual. In some fiords, dates of deglaciation obtained from marine shells associated with local marine limits do not vary significantly from the fiord head to the mid-fiord areas and this suggests that in places the marine limits of ca. 8,000 B.P. were formed during an extensive transgression that is tentatively related to a readvance of the fiord glaciers during Cockburn time. In certain areas the cockburn Moraines may even mark the greatest extent of late-Wisconsin ice. It is believed that the readvance is associated with increased precipitation during a general warming phase.

In the regional scheme the rapid disintegration of the Laurentide Ice Sheet by penetration of the sea into Hudson Bay and south to James Bay (at an estimated rate of 16 to 3.2 km yr^{-1}) is temporally (by ^{14}C dates) indistinguishable from the Cochrane and Cockburn readvances. All occurred within a few hundred years, centered on 8,000 B.P. The Cochrane readvance has been physically associated with the encroachment of the Tyrrell Sea and this hypothesis is attractive. Finally, the considerable difference between the Cochrane readvance, which was the final phase in fluctuations of the southern Laurentide ice margin, and the Cockburn readvance (*sensu stricto*) which was followed by an extensive period of slow retreat and readvances, is stressed.

A.A.

34. **ANDREWS, J.T., and J.D. IVES. 1978. "Cockburn" nomenclature and the late Quaternary history of the eastern Canadian Arctic. Arctic and Alpine Research 10(3):617-633.**

A system of end and lateral moraines, extending from near Frobisher, Baffin Island, to the west of the Penny Ice Cap, and roughly parallel to the fiord heads of the northeast coast to Bernier Bay, was identified in the 1960s and given the name "Cockburn end-moraine system". Since then the name "Cockburn" has been used in conjunction with several distinct types of stratigraphic units and landform assemblages. The three main uses are (1) Cockburn end-moraine system, Cockburn moraines, Cockburn Moraine, which are all morphostratigraphic units; (2) Cockburn Stade, which is a geologic-climatic unit; and (3) Cockburn Glacial Phase, which was originally defined as occurring between 8000 and 9000 radiocarbon years ago, and which is, therefore, a chronostratigraphic unit. Thus there is an ambiguity in present usage that has developed over the last 15 yr as knowledge of the glacial morphology and stratigraphy of the eastern Canadian Arctic has expanded. In this paper an attempt is made to reduce this ambiguity by preparing new definitions.

pA.A.

35. **ANDREWS, J.T., and G.H. MILLER. 1972. Quaternary history of northern Cumberland Peninsula, Baffin Island, N.W.T., Canada: Part IV. Maps of the present glaciation limits and lowest equilibrium line altitude for north and south Baffin Island. Arctic and Alpine Research 4(1):45-59.**

Maps of the glaciation limit and lowest equilibrium line altitude (ELA) are presented for southern and northern Baffin Island. The glaciation limit was determined by the "summit method"; the ELAs were determined by assuming a steady state accumulation area ratio of 0.65. Data were derived from the 1:250,000 map series based on between six and eight points per map. The isoglacihypses are roughly parallel to the east coast of the island and rise inland at approximately 4 m km^{-1}. Along the outermost coast a typical elevation is 700 m a.s.l. rising to between 1,000 and 1,300 m inland. There is evidence on the northern map that the glaciation limit declines from a high point to both the east (Baffin Bay) and the west (Foxe Basin). Enclosed, high contours exist in the vicinity of the Penny Ice Cap, the Barnes Ice Cap, and the heavily glacierized region near Pond Inlet and Bylot Island. ELAs are, on the average, 200 m below the glaciation limit. A study of features in Okoa Bay indicates that paleo-ELAs were once about 400 m lower than today during the late Quaternary. Analysis of the height of the average July 0°C isotherm, assuming an environmental lapse rate of 0.75°C per 100 m, indicates considerable variation on the initial analysis although subsequent work indicates that the relationship between the glaciation limit and the height of the July freezing level has broad, spatial correlation. Glaciation limit gradients from Norway, British Columbia, Greenland, and Baffin Island are compared and shown to be similar with a gradient of about 4 m km^{-1}.

A.A.

36. **ANDREWS, J.T., G.H. MILLER, A.R. NELSON, W.N. MODE, and W.W. LOCKE, III. 1981. Quaternary near-shore environments on eastern Baffin Island, N.W.T. In: Quaternary Paleoclimate. Edited by: W.C. Mahaney. Geo Abstracts, Norwich. pp. 13-44.**

The interrelationships between marine environments in Baffin Bay and the growth and disappearance of glacial ice on Baffin Island do not follow a simple mode of: atmospheric cooling = glaciation. This and other factors point to problems with the American

Stratigraphic Code's definition of "geologic-climate" units. The association of extensive glaciation on Baffin Island with periods of "warm" subarctic water inshore against Baffin Island is documented by a study of the distribution of subarctic marine molluscs in raised marine sediments from sections along the eastern coast of Baffin Island. Distribution maps of certain key taxa are shown for periods during the last (=Foxe) Glaciation and compared with the current northern range of these species. Correlation of the various raised marine strata is based on a similarity of D-alloisoleucene: L-isoleucene ratios for both the free and total fractions. Units with similar amino acid ratios are grouped into aminozones. We suggest that useful names for warm and cold water events are aquatherms and aquacalts, respectively.

Consideration of available radiometric dates and the kinetics of amino acid epimerization indicate that the Kogalu Member of the Clyde Foreland Formation and its chronocorrelative units, date from ca. 70,000 BP. This represents the youngest of three glacial/marine sedimentation cycles during the Foxe Glaciation. The raised marine sediments at Iron Strand, Labrador (Ives, 1977) may be younger than Kogalu, although pre-Holocene in age.

A.A.

37. ANDREWS, J.T., W.N. MODE, and P.T. DAVIS. 1980. Holocene climate based on pollen transfer functions, eastern Canadian Arctic. Arctic and Alpine Research 12(1):41-64.

Transfer functions are developed for a north-south transect in the eastern Canadian Arctic (from Clyde River to Fort Chimo) based on surface pollen samples. The Imbrie/Kipp and multiple stepwise linear regression models are used to show the statistical association between percentages of 19 pollen taxa and climatic variables (January, June, July, and summer temperatures, Young's index of summer warmth, and summer (JJA) precipitation). Multiple correlation coefficients are high and standard deviations of temperature estimates are less than ±1°C and 2.5 cm. The problem of the local variability of pollen in surface mosses is considered through an analysis of the results of the transfer functions on 69 additional modern surface samples from around Fort Chimo, Frobisher Bay, Pangnirtung, Broughton Island, and Clyde River. Good agreement exists between the predicted July temperatures based on the transfer functions and adjacent weather station records. The transfer functions are applied to four fossil peat pollen sequences on Cumberland Peninsula. These spectra provide a nearly continuous record that covers the last 6000 yr. Analysis of the fossil materials provides estimates of July T°C and summer precipitation (cm). A period of warmer and wetter conditions generally prevailed between 6000 and 4000 BP although this climate was punctuated by cooler conditions ca. 4800 yr ago. Over the last 3600 yr the pollen record from Windy Lake shows a progressive decline in July temperature. Superimposed on this trend are a number of temperature oscillations which show correspondence with other regional proxy climatic records.

A.A.

38. ANDREWS, J.T., and H. NICHOLS. 1981. Modern pollen deposition and Holocene paleotemperature reconstructions, central northern Canada. Arctic and Alpine Research 13(4):387-408.

The relative modern pollen spectra is reported for a transect from the edge of the boreal forest of Keewatin (ca. 60°N), north-eastward to the high arctic/polar desert environments of Clyde River, Baffin Island (ca. 71°N). Two hundred and ninety-three surface moss polsters are analyzed from 29 sites. Thirteen modern pollen taxa (*Alnus*, *Betula*, *Picea*, Chenopodiaceae, *Pinus*, *Salix*, *Artemesia*, Caryophyllaceae, Compositae, Gramineae, Cyperaceae, Ericaceae, and *Sphagnum*) are used in association with estimates of present temperature and precipitation, to construct transfer function equations from fossil pollen diagrams. Equations are derived using the Imbrie/Kipp (1971) approach and multiple regression procedures. The resulting equations are all statistically significant with multiple correlation coefficients for summer temperatures of better than 0.9 with standard errors of - 1.0°C or less.

The transfer functions are used on four published pollen diagrams (Nichols, 1975) to predict July temperature. The resulting time-series are presented as standardized departures from the mean July T C at each of the four sites. A generalized reconstruction of the July temperature history is then made by taking average departures for each of the four sites over the last 6,000 years. This shows (1) temperatures above average between 5,500 and 4,000 BP; (2) temperatures below average (or average) between 4,000 and 3,000 BP; (3) temperatures above average between 3,000 and 2,000 BP; and (4) temperatures below average between 2,000 and the last few hundred years. In addition, on the basis of multivariate statistical analysis, we define four geographical pollen assemblage regions. Proceeding from south to north the pollen assemblages are Region I: *Betula*/ *Pinus*/ *Picea*/Ericaceae; Region II: *Betula*/ *Pinus*/Ericaceae/ *Alnus*; Region III: Ericaceae/ *Salix*/Cyperaceae/ *Pinus*; and Region IV: Gramineae/Cyperaceae/Ericaceae/ *Salix*.

A.A.

39. **ANDREWS, J.T., W.W. SHILTS, and G.H. MILLER. 1983. Multiple deglaciations of the Hudson Bay Lowlands, Canada, since deposition of the Missinaibi (Last-Interglacial?) Formation. Quaternary Research 19(1):18-37.**

The stratigraphic record in the James and Hudson Bay Lowlands indicates that the sequence of glacial events at the geographical centre of the 12.6 x 10^6 km^2 Laurentide Ice Sheet may have been more complex than hitherto imagined. Isoleucine epimerization ratios of *in situ* and transported shells recovered from till and associated marine and fluvial sediments cluster into at least 4 discrete groups. Two alternative explanations of the data are offered, of which we strongly favor the first. Hypothesis 1: Setting the age of the "last interglacial" marine incursion, the Bell Sea, at 130,000 yr B.P. results in a long-term average diagenetic temperature for the lowlands of +0.6°C. Using this temperature enables us to predict the age of shells intermediate in age between the "last interglaciation" and the incursion of the Tyrrell Sea 8000 yr ago. Between these two interglacial marine inundations, Hudson Bay is predicted to have been free of ice along its southern shore about 35,000, 75,000 and 105,000 yr ago based on amino acid ratios from shells occurring as erratics in several superimposed tills and fluvial sediments. These results suggest (1) that traditional concepts of ice-sheet build-up and decay must be reexamined; (2) that "high" sea levels may have occurred during the Wisconsin Glaciation; and (3) that a critical reappraisal is required of the open ocean $\delta^{18}O$ record as a simple indicator of global ice volume. An alternative, Hypothesis 2, is also examined. It is based on the assumption that the 35,000-yr-old deposits calculated on the basis of Hypothesis 1 date from the "last interglaciation"; this, in effect, indicates that the Missinaibi Formation, commonly accepted as sediments of the "last interglaciation", are about 500,000 yr old and that the effective diagenetic temperature in the lowlands during approximately the last 130,000 yr has been close to -6°C. We argue for rejection of this alternative hypothesis.

A.A.

40. **ANDREWS, J.T., and K. TYLER. 1977. The observed postglacial recovery of Québec and Nouveau-Québec since 12,000 BP. Géographie physique et Quaternaire 31(3-4):389-400.**

Radiocarbon dated relative sea levels, the tilts of proglacial lake shorelines and raised marine shorelines, the directions of the tilt of these features, and postglacial delevelling are used to construct six isobase maps showing relative sea level movements over the last 12,000, 10,000, 8,000, 4,000 and 2,000 years. No map has more than 30 control points and usually there are only 12 "good" points controlling the isobase patterns. Each map shows the relationship of the isobases to the current ice sheet extent. Along the southern margin of the Laurentide Ice Sheet, the maximum postglacial emergence has been quite uniform with the 240 to 200 m isobase always close to the ice margin. Along the northeastern margin of the ice sheet, the postglacial emergence at the retreating ice edge was closer to 100 m. Equidistant diagrams are drawn along planes southeast from southern Hudson Bay and eastward from Southampton Island. If these diagrams are compared on a Shoreline Relation Diagram, the two profiles appear similar and compare moderately well with a theoretical SR Diagram published in 1969. The isobases show a major uplift center located around the area of James

Bay and southern Hudson Bay where a maximum emergence of nearly 300 m occurred in the last 7,500 years. High marine limits southwest of Ungava Bay need to be dated because if they date close to 8,000 B.P. as we suggest, then more emergence is suggested for the region southwest of Ungava Bay than we currently allow for.

A.A.

41. **ANDREWS, J.T., P.J. WEBBER, and H. NICHOLS. 1979. A late Holocence pollen diagram from Pangnirtung Pass, Baffin Island, N.W.T., Canada. Review of Paleobotany and Palynology 27:1-28.**

A 1.2 m section of organic-rich sediment from near Windy Lake, Pangnirtung Pass, Baffin Island, Canada, is dated by twelve radiocarbon assays which indicate that the sediment accumulated at an average rate of 6.5 cm 100 yr^{-1}. The base of the studied exposure is about 2500 years old, whereas the sediment at a depth of 4 to 9 cm is dated about 650 years old. The sampling interval for pollen averages one sample every 39 years. The section is described in terms of the lithology of the inorganic matrix, in the plant growth form and moisture preference of the pollen taxa, and in the variations in the influx of exotic pollen (*Alnus*, *Picea*, and *Pinus*). Principal Components Analysis and clustering of pollen levels were used to zone five different groupings of the pollen taxa "objectively". Both relative and "absolute" pollen values were used in these various steps. Pollen accumulation varied between 24 and 14,300 grains cm^{-2} yr^{-1} with a median value of 501. Thirteen biozones are recognized primarily from changes in the rates of pollen accumulation and diversity. The broad climatic interpretation of the pollen stratigraphy has similarities and differences from nearby glacial moraine chronologies. Sharp increases in exotic pollen (especially *Alnus*) are provisionally associated with major advection of southerly air toward Cumberland Peninsula, southeastern Baffin Island.

A.A.

42. **ANDREWS, M., and J.T. ANDREWS. 1980. Baffin Island Quaternary environments. An annotated bibliography. Institute of Arctic and Alpine Research, Occasional Paper 33:1-123.**

Over four hundred and sixty references, the majority of which include abstracts from secondary sources, are presented. Covering the broad subject area of the Quaternary environment of Baffin Island, Canada, they are arranged according to thirteen more specific subject categories. An author index follows the bibliography. Two figures and some introductory remarks give the user a reference framework.

A.A.

43. **ANTEVS, E. 1931. Late-Glacial correlations and ice recession in Manitoba. Geological Survey of Canada Memoir 168:1-76.**

The disappearance of glacial Lake Ojibway in northern Ontario and Quebec, when the ice front stood north of Cochrane, sets practically a limit to the extension of the varved clay chronology in the region south of James Bay. A study of the varved clays from the last stages of glacial Lake Agassiz in northern Manitoba was, therefore, carried out during the summer of 1929.

In order to correlate the Late-Glacial ice borders and events in northern Manitoba with those in western Quebec and eastern Ontario, the existing data concerning the direction of the ice flow, the moraines, etc., were compiled. This led to an attempt at a general correlation of the Late-Glacial of the East and the Middle West. The results of these various investigations are herewith presented. Furthermore, the probable correlation of the Late-Glacial of North America and of Europe, as well as the basis of attempted correlations between clay varves from America and Europe, are discussed in some detail. A suggestion for a division of the late Quaternary of North America is also presented.

P.

44. **ANTEVS, E. 1955. Varve and radiocarbon chronologies appraised by pollen data. Journal of Geology 63(5):495-499.**

Natural correlation with climatic ages of Canadian postglacial forest types, deduced by Potzger and Courtemanche, confirms the well-suggested view that the ice border oscillations at Cochrane antedated the Altithermal which culminated ca. 6,000 years ago. The postglacial crustal rise of the James Bay country required 8,000-10,000 years according to Gutenberg. The Cochrane must be the correlative of the European Salpausselkä stage and be some 10,000-11,000 years old. Since the ice retreat from Milwaukee to Cochrane comprised at least 7,000 years, the radiocarbon age of the Two Creeks forest bed of 11,400 years must be much too low.

A.A.

45. **ARCHER, D.R. 1966. Deglaciation and post-glacial emergence in the vicinity of Little Whale River, New Quebec - a preliminary report. McGill University Sub-Arctic Research Laboratory, Research Paper No.21:1-17.**

Describes field investigations in this area into various aspects of late- and post-glacial history. The upper marine limit was measured by altimetry and the chronology of uplift by lichenometry. Results are graphed and illustrated. Some problems met with in the lichenometric observations are mentioned. Emergence since deglaciation has been continuous, but was most rapid in the early stages. Recent uplift has been at 4-7 ft/century. Some findings relevant to the ice slope and movement between Hudson Bay and Labrador-Ungava are discussed. The upper marine limit in this area is more than 900 ft above present sea level.

A.B.

46. **ARMSTRONG, J.E. 1981. Post-Vashon Wisconsin glaciation, Fraser Lowland, British Columbia. Geological Survey of Canada Bulletin 322:1-34.**

The late Wisconsin Fraser Glaciation in southwestern British Columbia commenced on the mainland between 23,000 and 26,000 radiocarbon years ago and terminated about 11,000 radiocarbon years ago. It reached its climax during the Vashon Stade about 15,000 to 15,500 years ago when it extended south to 47°N. The Vashon ice was more than 1800 m thick in the Fraser Lowland, and the weight of the ice isostatically depressed the area at least 350 m and possibly 400 m or more.

Withdrawal of Vashon ice was rapid, and from about 13,000 to 11,000 years BP most of the Fraser Lowland was invaded by the sea. During this interval the eastern part of the Fraser Lowland was occupied by a piedmont glacier or glaciers that at various times retreated, were stationary, or surged forward. The glacier or glaciers terminated in the sea for much of their history, probably in a manner similar to the glaciers of the Yakutat Bay area of Alaska. Throughout the period glaciomarine sediments were formed largely from dropstones and debris deposited into seafloor muds by floating pieces of ice (including bergs). During surges and standstills drift was deposited in places above sea level and on the seafloor. The deposits laid down during the occupation of the sea comprise the Fort Langley Formation and the Capilano Sediments.

Isostatic, eustatic and tectonic adjustments between the withdrawal of Vashon ice and withdrawal of the sea were not uniform for the whole area; however, at least two major submergences separated by unusually rapid emergences are indicated. The final withdrawal of the sea and disappearance of floating ice in the eastern part of the Fraser Lowland coincided with a final surge of piedmont ice. The deposits laid down during this last stade have been called Sumas. This ice apparently began to advance about 11,400 years ago when sea level was at least 50 m higher than at present. The date at which Sumas ice disappeared is indefinite but was probably about 11,000 years ago, at which time the sea no longer occupied the area.

A.A.

47. ARMSTRONG, J.E., and J.J. CLAGUE. 1977. Two major Wisconsin lithostratigraphic units in southwest British Columbia. Canadian Journal of Earth Sciences 17(7):1471-1480.

Two lithostratigraphic units, Quadra Sand and the Cowichan Head Formation, are overlain by Vashon till and associated glacial sediments and underlain by Dashwood and Semiahmoo drift deposits in coastal southwest British Columbia. Each unit is formally described and stratotypes are presented.

Quadra Sand consists of cross-stratified, well-sorted sand, minor gravel, and silt deposited as outwash in front of glaciers advancing into the Georgia Depression at the beginning of the Fraser Glaciation. It is diachronous, deposition having commenced earlier than 29,000 BP at the north end of the Georgia Depression but not until after 15,000 years BP at the south end of the Puget Lowland.

The Cowichan Head Formation, deposited during the Olympia nonglacial interval, underlies Quadra Sand and consists of parallel-bedded silts, sand, and gravel, in part plant-bearing. The unit is divisible into a lower marine member and an upper fluvial and estuarine member.

A.A.

48. ARMSTRONG, J.E., D.R. CRANDELL, D.J. EASTERBROOK, and J.B. NOBLE. 1965. Late Pleistocene stratigraphy and chronology in southwestern British Columbia and northwestern Washington. Geological Society of America Bulletin 76:321-330.

Six geologic-climate units are proposed for the late Pleistocene sequence in southwestern British Columbia and northwestern Washington. They include two major units, the Olympia Interglaciation and the Fraser Glaciation, and four subdivisions of the latter - the Evans Creek, Vashon, and Sumas Stades, and the Everson Interstade. The Olympia Interglaciation is a nonglacial episode that started at least 36,000 years BP and continued until the advance of Cordilleran glacier ice during the Fraser Glaciation. During the Evans Creek Stade, alpine glaciers formed in the mountains of western Washington and British Columbia while nonglacial sediments were still being deposited in the southern Puget Lowland. Further growth of glaciers in British Columbia resulted in the formation of the Cordilleran ice sheet. This ice entered the northern end of the area after 25,000 years BP but did not reach the southern end until after 15,000 years BP. The Vashon Stade of the Fraser Glaciation began with this advance of Cordilleran ice into the lowlands. It ended with the beginning of marine and glaciomarine conditions there, which commenced in the southern Puget Lowland about 13,500 years BP and in the Strait of Georgia about 13,000 years BP. The episode represented by the marine conditions is called the Everson Interstade and lasted about 2000 years, during which the sea contained much floating ice. The Interstade ended when the land rose with respect to the sea level forcing withdrawal of the sea and the disappearance of floating ice in most of northwestern Washington and southwestern British Columbia; in the eastern part of the Fraser Lowland this event coincided with the advance of a valley glacier during the Sumas Stade.

A.A.

49. ARMSTRONG, J.E., and S.R. HICOCK. 1975. Quaternary landscapes; present and past at Mary Hill, Coquitlam, B.C. Geological Survey of Canada Paper 75-1B:99-103.

Commencing with the oldest sediments exposed the geological history of Mary Hill may be summarized as follows:

1. The oldest Highbury Sediments found in the pit are organic deposits. ...The climate at this time may have been as warm as the present day climate, however, only pollen and insect studies will confirm this.
2. The Highway swamp deposits are overlain by fluvial sediments... These fluvial deposits, ...are possibly proglacial in origin, representing a climatic interval between a relatively warm climate and a glacial climate.
3. A major glaciation, represented by the Semiahmoo Drift, resulted from this cooling climate.
4. As a result of climatic warming, the Semiahmoo glaciation came to a close.
5. The Quadra Sediments of the Olympia Interglaciation were deposited during this second warm period which may have lasted 25 000 years. ... The climate during this period is believed to have been similar or slightly cooler than the present day climate.
6. The Quadra deposits are overlain by thick fluvial sediments which were deposited by streams that channelled into the swamps. These fluvial sediments, which have been included in the Quadra lithologic unit, probably were laid down during the transitional period from a relatively warm to a glacial climate.
7. A continued cooling resulted in a glacial climate once again, commencing about 22 000 years ago and lasting about 11 000 years. The Mary Hill pit records three local advances of ice during this period, each accompanied by deposition of till and glaciofluvial sediments.

pA.C.

50. ASHWORTH, A.C. 1977. A late Wisconsinan Coleopterous assemblage from southern Ontario and its environmental significance. Canadian Journal of Earth Sciences 14(7):1625-1634.

A flood debris assemblage of fossil Coleoptera is described from a 10,600 year old terrace deposit in southern Ontario. It is a small sample of the fauna that had colonized the region after deglaciation and although the species are extant, the assemblage is a surprising mixture of faunistic elements for which there is no known modern analog. Species with wide-spread boreal, arctic-alpine, northwestern boreal, southern boreal, and eastern distributions are recorded. The present ecologic and geographic distributions of the species indicate a valley environment with similar habitat diversity and climate to those which characterize the tundra-forest transition zone of northern Canada. This interpretation is supported by macroscopic plant evidence but conflicts with pollen evidence which implies a climate with warmer summers. To resolve the problem it is proposed that the valley fauna and flora survived in an isolated cold microenvironment surrounded by regionally warmer conditions and for which analogies presently exist on the north and east shores of Lake Superior.

A.A.

51. AUER, V. 1930. Peat bogs in southeastern Canada. Geological Survey of Canada Memoir 162:1-32.

The peat bogs of southeastern Canada thus seem to indicate that the lower layers formed during a warm, dry period; that this was followed by a moist period which, judging by the presence of deciduous trees, was also probably warm; that this was succeeded by a dry, warm period, and this in turn by a moist period which possibly was comparatively cool as deciduous trees decreased in quantity. The climatic changes correspond in a general way, at least, to those that affected Europe in post-Glacial time. The early dry, warm period corresponds with the Boreal period; the next, the moist probably warm period, with the Atlantic period; the third, the dry, warm period with the sub-Boreal period; and the last, the moist, probably cool period, with the sub-Atlantic period.

Excerpt

52. BAKER, D.G. 1980. Botanical and chemical evidence of climatic change: a comment. Journal of Interdisciplinary History 10(4):813-819.

A review of several proxy data methods to estimate past climates and the "inherent problems which may limit the ability of each method to provide the kind of quantitative results often asserted for them."

A.B.S.

53. BAKER, R.G. 1981. Interglacial and interstadial environments in Yellowstone National Park. In: Quaternary Paleoclimate. Edited by: W.C. Mahaney. Geo Abstracts, Norwich. pp. 361-375.

The Holocene is characterized on pollen diagrams from Yellowstone National Park by high percentages of pine, mostly diploxylon, and low percentages of sagebrush, grass, juniper, spruce, and fir.

Cold interstadial periods are represented by low pine percentages, of mostly the haploxylon type, and high percentages of sagebrush, grass, and juniper pollen.

Warm interstadial periods are represented by maxima of spruce and fir pollen and by intermediate percentages of pine, mostly haploxylon, during the cooler phases. At times of maximum warmth, percentages of pine pollen are still at intermediate levels, but are mostly of the diploxylon type; spruce and fir pollen percentages are also at intermediate levels. Grass, sagebrush, and juniper are at intermediate percentages throughout the warm interstadial interval.

The single interglacial pollen sequence is characterized by a Douglas-fir pollen maximum, by relatively high percentage of pine pollen, mostly haploxylon, and by low percentages of fir, spruce, sagebrush, grass, and juniper.

pA.C.

54. BARRY, R.G. 1960. The application of synoptic studies in palaeoclimatology: a case study for Labrador-Ungava. Geografiska Annaler 4(1):36-44.

Examines characteristic airflow pattern types over this region, and their relation to local climatological features. A complex response of regional climatic conditions to changing synoptic situations is demonstrated. Conditions of the winters 1956-57 and 1957-58 are discussed and analyzed; their possible influence on present and Pleistocene glaciation is considered. Theories on the glacial history and field evidence of final deglaciation of Labrador-Ungava are reviewed.

A.B.

55. BARRY, R.G. 1966. Meteorological aspects of the glacial history of Labrador-Ungava with special reference to atmospheric vapour transport. Geographical Bulletin 8(4):319-340.

The patterns of vapour transport and flux convergence over northeastern North America during two winter seasons are discussed with reference to their implications for the palaeoclimatology of Labrador-Ungava. Various circulation models which have been advanced to account for the glaciation of the area are examined in the light of the calculations. Mean total vapour flux is from the west, but the mean eddy component is essentially from the south and the convergence of this eddy flux dominates the pattern of total flux convergence during winter. No unique circulation type appears responsible for large flux convergence over the region, although it seems possible that incursions of cyclonic easterly flow with low index circulations are important for the development of an ice sheet. The contribution of different airflow patterns to the seasonal snowfall is examined for stations in the area and the significance of the amounts is discussed.

Statistical probabilities of low summer temperatures are also considered, following the hypothesis that this is more important than winter snowfall, and the paper concludes with some rough estimates of the time required for ice-sheet growth.

A.A.

56. **BARRY, R.G. 1973. Conditions favoring glacierization and deglacierization in North America from a climatological viewpoint. Arctic and Alpine Research 5(3):171-184.**

Approaches to paleoclimatic reconstruction on a local-regional scale through synoptic climatology and on a global scale through numerical modeling are discussed. Synoptic climatological considerations indicate the importance of southeasterly flow components for glacierization in Baffin Island, Labrador-Ungava, and Keewatin. It appears that no individual synoptic pattern is responsible for most of the ablation of ice bodies in eastern Baffin Island so that a synoptic climatological approach to deglacierization is likely to be indeterminate.

The NCAR global circulation model with modified surface boundary conditions has been used to simulate the circulation at the last glacial maximum in January and July. The input data include the vertical and horizontal extent of ice, albedos relating to snow cover and vegetation distributions, and ocean temperature. Comparisons with control cases for present conditions show weaker jet maxima, but rather stronger low to mid-tropospheric westerly flow in the Northern Hemisphere, than at present for January and stronger upper westerlies in July. The MSL pressure maps, which must be interpreted with care in the vicinity of the ice sheets are also discussed. The reconstructions provide a starting point on which hypotheses relating to the Wisconsin deglaciation must be based.

A.A.

57. **BARRY, R.G. 1975. Climate models in palaeoclimatic reconstruction. Palaeogeography, Palaeoclimatology, Palaeoecology 17(2):123-137.**

A survey of global climate modelling is presented. Various numerical modelling approaches - diagnostic, vertical column, zonally averaged and global circulation - are outlined, with emphasis on their applicability to particular types of problems and their limitations. Palaeoclimatic data available for model input and verification are compared with data required as model input and model-generated results, respectively.

A.A.

58. **BARRY, R.G. 1977. Short-term climatic fluctuations. Progress in Physical Geography 1(1):114-125.**

While short-term circulation changes may affect at least a hemisphere, there are regional differences in climate response as a result of the tropospheric wave structure. It is dangerous to infer global changes from local data, and our data-base does not allow us to establish the global record over past years. Inherent variability in climatic and especially precipitation patterns is now better understood. While most changes are internal to the earth-atmosphere system, some are due to solar variation.

G.A.

59. BARRY, R.G. 1981. The nature and origin of climatic fluctuations in northeastern North America. Géographie physique et Quaternaire 35(1):41-47.

Features of the atmospheric circulation and climate of northeastern Canada are reviewed. In particular, the role of the upper level trough and its variability are discussed. It is shown that longitudinal displacements of the mean summer trough create anomalies of both air temperature and sea-ice conditions in the region of Baffin Island. Climatic anomaly patterns in Labrador-Ungava and Keewatin associated with trough displacements are also summarized. Two examples of the application of such information to paleoclimatological questions are discussed. One concerns the influx of "exotic" tree pollen into Baffin Island and its previously postulated relationship to southerly airflow. It is concluded that pollen peaks cannot yet be reliably used as a paleowind index. The pattern of glacial inception and ice sheet extension during the Last Glacial Maximum is also briefly considered in the light of the available climatic information. Finally, the role of the orbital variations affecting the seasonal pattern of solar radiation is discussed with reference to the last glacial cycle.

A.A.

60. BARRY, R.G., J.T. ANDREWS, and M.A. MAHAFFY. 1975. Continental ice sheets: conditions for growth. Science 190(4218):979-981.

The conditions required for the development of major ice sheets in eastern Canada appear to have been approximated by those of the Little Ice Age in the 17th through the 19th centuries. Former extensive snowbanks from this period have been mapped from lichen-free terrain visible on ERTS[1] imagery. The climatic changes required to initiate the necessary snow line lowering may involve only a minor summer cooling. Simulations with an ice-flow model reproduce plausible ice centers, but the rate of ice sheet buildup is slower than that suggested by geological evidence of world sea level lowering form 120,000 to 115,000 years before the present.

A.A.

61. BARRY, R.G., W.H. ARUNDALE, J.T. ANDREWS, R.S. BRADLEY, and H. NICHOLS. 1977. Environmental change and cultural change in the eastern Canadian Arctic during the last 5000 years. Arctic and Alpine Research 9(2):193-210.

Archaeological research suggests that cultural changes in the Canadian Arctic are closely linked to enviromental changes. Current knowledge of postglacial climate and marine conditions in the eastern Canadian Arctic - an area demonstrably sensitive to small fluctuations in these conditions - is reviewed in the context of the prehistoric cultural sequence. Most of the major cultural events since 4500 BP appear to correlate well with the paleoclimatic conditions inferred from environmental data although specific causal mechanisms cannot be documented.

The expansions of Arctic Small Tool tradition (ASTt) and later of the Thule people seem to be related to warmer climatic conditions, whereas the evolution and decline of Dorset culture seems to show an inverse relation to temperature trends. More work is required on the dating of environmental and cultural changes and on the precise nature of possible interactions between environmental factors and cultural response.

A.A.

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[1] Ed. note: Earth Resources Technology Satellite.

62. **BARRY, R.G., R.S. BRADLEY, and J.D. JACOBS. 1975. Synoptic climatological studies of the Baffin Island area. In: Climate of the Arctic. Edited by: G. Weller and S.A. Bowling. 24th Alaska Science Conference, University of Alaska, Fairbanks. pp. 82-90.**

Examination of present and past glacierization of eastern Baffin Island in relation to climate suggests that a decline in summer temperatures in the area during the 1960s, and perhaps also the concomitant marked increase in persistence of sea ice in Baffin Bay, is related to a higher frequency of easterly and northeasterly airflow. Apart from the summer cooling, winters in eastern Baffin Island were milder and more snowy in the 1960s. Such anomalies are associated with a westward displacement of the mean 700 mb trough over eastern North America which encourages northward movement of cyclones into Baffin Bay. The evident sensitivity of this area to climatic fluctuations on both short and long time scales makes it a rewarding area for interdisciplinary environmental studies.

pA.A.

63. **BARRY, R.G., D.L. ELLIOTT, and R.G. CRANE. 1981. The paleoclimatic interpretation of exotic pollen peaks in Holocene records from the eastern Canadian Arctic: a discussion. Review of Palaeobotany and Palynology 33(2-4):153-167.**

Processes involved in the transport of "exotic" tree pollen and its deposition in eastern Arctic Canada are reviewed. Synoptic meteorological situations favoring transport northward from the boreal forest are analyzed via boundary-layer trajectory computations. To account for reported exotic pollen peaks in Holocene peat deposits on Baffin Island, the necessary increase in frequency of southerly wind components may be as much as an order of magnitude, which could not be accommodated in the available time interval of pollen release, if sources from all of the Canadian boreal forest are considered. If only Labrador sources are involved, the absolute increase in southerly airflow may be unexceptional. It is also shown that changing airflow direction cannot be directly linked with longitudinal displacements of the 700 mbar trough at 75°W.

Other possible factors that could have produced peaks in exotic pollen include variable sedimentation rates, variable pollen production, or a non-linear relationship between airflow frequency and pollen deposition.

A.A.

64. **BARRY, R.G., J.D. IVES, and J.T. ANDREWS. 1971. A discussion of atmospheric circulation during the last ice age. Quaternary Research 1(3):415-418.**

The authors review Lamb and Woodroffe's (1970) reconstructions of atmospheric circulation for several phases of the last Ice Age. Their discussion is concerned "with the proposed timing of events during the inception phase of the last Ice Age." Work by other researchers is considered, and the conclusion is reached that development of the Lamb and Woodroffe hypothesis "will require a much more rigorously based chronology, and a closer fusing of geological and palynological field data with modern techniques in synoptic climatology.

A.B.S

65. **BARTLETT, G.A., and L. MOLINSKY. 1972. Foraminifera and the Holocene history of the Gulf of St. Lawrence. Canadian Journal of Earth Sciences 9(9):1204-1215.**

Foraminifera have been utilized to interpret the response of waters in the Gulf of St. Lawrence to climatic changes during the Holocene. Sediment cores (up to 1000 cm long) from the Gulf of St. Lawrence and environs, are characterized throughout by meager foraminiferal faunas. The microfaunas are characteristic of marginal marine environments and are typified by low foraminiferal numbers (less than 300 and generally less than 100 per unit sample), few genera and species, and hyposaline, shallow-water assemblages. The microfaunal information indicates that marine waters were more brackish and much shallower during the latter stages, and immediately following the Wisconsin glaciation. Shallow-water foraminiferal species such as *Elphidium incertum clavatum*, *Islandiella islandica*, and *I. teretis* are commonly the first to inhabit cool temperate to northern environments after glacial retreat. Consequently, because of the absence of deep water marine microfaunas it is believed that many areas in the Gulf of St. Lawrence were at least 100 to 200 m shallower than at present.

The Holocene history of the area is one of transition from a rapidly fluctuating brackish water environment, to one which is more consistent with the present environment. The presence of *Globigerinoides ruber* (pink), a species commonly associated with subtropical waters, intermixed with the eurybathic benthonic fauna, indicates distinctive lateral and vertical water-mass zonation in a restricted geographic area. Warm water incursions into the Gulf of St. Lawrence from the Gulf Stream, which contained the subtropical foraminiferal species *Globigerinoides ruber* and *Globorotalia menardii*, were intermittent, whereas a persistent cold-water marine influence from the Arctic via the Labrador Current is indicated by the presence of *Globigerina pachyderma*. The adjoining Scotian Shelf faunas, alternating from sparse, to prolific and diverse, during the Holocene, suggest that conditions there were not significantly different from those in the Gulf of St. Lawrence.

Extremely brackish and/or shallower waters were present in most of the western Laurentian Channel and shelf waters of the Gulf of St. Lawrence until recently (<6400 ± 130 yr B.P.). The baymouth bars, persistent features restricting circulation with most bays, estuaries, and lagoons adjoining Prince Edward Island and New Brunswick were established between 4540 ± 180 and 2235 ± 155 yr B.P. Sediments containing subtropic and arctic planktonic species, alternating with eurythermal benthonic species, are indicative of environmental extremes throughout the Holocene. It is believed that many of these marine fluctuations were neither recorded nor preserved in adjoining continental sediments of equivalent age.

A.A.

66. BARTLEY, D.D., and B. MATTHEWS. 1969. A palaeobotanical investigation of postglacial deposits in the Sugluk area of northern Ungava (Quebec, Canada). Review of Palaeobotany and Palynology 9(1-2):45-61.

A number of peat deposits, mainly associated with raised beaches, were studied in the Sugluk region of northern Ungava. The peats were exposed in sections cut by river erosion and usually showed a succession of marine sands, peats and windblown sand. Samples were taken for the analysis of pollen and macroscopic remains. The conclusions may be summarized as follows:

1) Pollen analysis suggests that, during the period represented by the deposits, the area has been covered by treeless tundra.

2) The alternation of dated peats and sands can be interpreted in relation to the climatic scheme worked out by Nichols (1967) for Keewatin. There was: a) a warm period represented by peaty deposits dated about 4,000 years and 2,800 years B.P.; b) a cold period from about 2,800 to 1,600 years B.P., with deposition of windblown sand at one site; c) a warm and moist period from 1,600 to 670 years B.P. characterised by a considerable development of peat; d) a second cold period characterised by the cessation of peat growth and the development of sand dunes.

3) The development of living *Sphagnum* appears to have followed the amelioration of climate in this century.

A.S.

67. **BASSETT, I.J., and J. TERASMAE. 1962. Ragweeds, *Ambrosia* species, in Canada and their history in postglacial time. Canadian Journal of Botany 40(1):141-150.**

Specific differences of *Ambrosia artemisiifolia*, *A. trifida*, and *A. coronapifolia* are described and their present Canadian distributions are reported in detail. *Ambrosia* pollens, identified in fossil assemblages as either *A. artemisiifolia* or *A. trifida* with a few in the size range of *A. coronopifolia*, were somewhat more abundant in late-glacial deposits than in younger postglacial sediments except the subrecent ones. It is only within the last 200 years that ragweeds have again become abundant in eastern Canada. The migration and spread of the three ragweed species in eastern and western Canada through postglacial time are discussed. There is evidence through pollen profiles that *Ambrosia* species existed further northward in Ontario than they do at the present time. ...It may be of interest to note that specific differences of *Ambrosia artemisiifolia*, *A. trifida*, and *A. coronopifolia* are described and their present Canadian distributors are reported in detail. *Ambrosia* pollen has been found in southern Ontario and Quebec in interglacial deposits older than 60,000 years.

A.A.+

68. **BECK, A.E. 1979. The effect of Pleistocene climatic variations on the geothermal regime in Ontario; a reassessment; discussion. Canadian Journal of Earth Sciences 16(7):1515-1517.**

Beck discusses the article by Allis (1978). He reviews the assumptions made by Allis, the results obtained, and concludes that "the problem is a difficult one and it is not solved by the substitution of one simplistic approach for another." He then suggests that the approach of Cermak (1971) may prove more useful to follow.

A.B.S.

69. **BECK, A.E., and A.S. JUDGE. 1969. Analysis of heat flow data--I. Detailed observations in a single borehole. Geophysical Journal of the Royal Astronomical Society 18:145-158.**

Heat flow data from a 600-m deep diamond drilled borehole in southwestern Ontario has been used to estimate how short a section of borehole will give a valid heat flow value, to test for recent and ancient climatic changes, underground waterflows and the variation of terrestrial heat flow with depth. Temperatures were repeatedly measured at 3-m intervals; measurements of thermal conductivity, density and porosity were made on specimens sampled at approximately 4-m intervals along the length of the hole. The mean heat flow for the whole borehole before applying any corrections is 0.76 h.f.u. while after correcting for the Wisconsin glaciation the mean value is 1.17 h.f.u., but in both cases some 30 to 100-m sections of the borehole differ by ±20 per cent from the mean values. The differences cannot be entirely explained as being due to structure, topography, climatic changes or underground water-flows.

A.S.

70. **BEDNARSKI, J. 1978. Holocene glacial and periglacial environments in the Whistlers Creek Valley, Jasper National Park (118°6'W, 52°49'N). American Quarternary Association, National Conference, Abstracts 5:185.**

The head of Whistlers Creek Valley is occupied by two cirque glaciers which show evidence of retreat. Both glaciers have active tongue-shaped rock glaciers immediately downvalley. Within one of the rock glaciers large thaw pits and exposures of foliated ice, dipping upvalley, suggest buried glacier ice. Debris supply by avalanching and rockfall are considered the major causes of burial. Tilting trees indicate that one of the rock glaciers has advanced ~ 1 m in the last 45 years. Superimposed lobes on both rock glaciers suggest two periods of recent activity. These periods have been lichenometrically dated using *Rhizocarpon geographicum* ~ 1770 and 1885 AD for one rock glacier, and older than 1700 AD and 1910 AD for the other.

An inactive spatulate and several lobate rock glaciers were also identified. Total lichen cover, soil development and rock weathering criteria have established that these relic rock glaciers formed during a substantially older period. Radiocarbon dates and tephra deposits, however, are not yet available.

Turfbanked and stonebanked lobes and terraces, polygons, frost boils and sorted stripes are widespread. A number of solifluction forms show evidence of reactivation. Gliding blocks up to 4 m in length are ploughing gentle, vegetated slopes leaving furrows up to 20 m in length. The size and significance of these blocks warrant further research.

A.A.

71. **BENTLEY, P.A., and E.C. SMITH. 1954-55. The forests of Cape Breton in the seventeenth and eighteenth centuries. Proceeding of the Nova Scotian Institute of Science 24(part I):1-15.**

A description of the primeval forests of Cape Breton Island has been compiled from the accounts of observers and writers in the seventeenth and eighteenth centuries. As an aid in locating the areas described a map has been constructed showing the probable routes followed by these people in their travels about the island. The accounts used were those of Nicholas Denys (1672), the Sieur de la Roque (1752), Thomas Pichon (1760), an anonymous account (1758), Thomas Jeffreys (1760), Samuel Holland (1768), and Joseph Bouchette (1832).

The records left by these men form a fairly complete description of the forests which covered a coastal strip about the island and the Bras d'Or Lake, an area now largely cleared and settled. From this it appears that the forests consisted largely of the same associations which now make up the climax Hemlock - White Pine - Northern Hardwood forests of the untouched areas of the island. The forest at the edge of the northern plateau, a boreal forest mainly of fir, has survived relatively untouched, and the poor type forest of fir and spruce on the south and south-east coasts which is prevalent there today was in existence three hundred years ago. It is thought that this latter forest is related to the Fir Edaphic climax of Nichols. Of particular interest in the accounts is the mention of elm in the river valleys and the frequent reference to oak and ash throughout the hardwood forests since both species are comparatively rare today.

A.A.

72. **BERNABO, J.C., and T. WEBB, III. 1977. Changing patterns in the Holocene pollen record of northeastern North America: a mapped summary. Quaternary Research 8(1):64-96.**

By mapping the data from 62 radiocarbon-dated pollen diagrams, this paper illustrates the Holocene history of four major vegetational regions in northeastern North America. Isopoll maps, difference maps, and isochrone maps are used in order to examine the changing patterns within the data set and to study broad-scale and long-term vegetational dynamics. Isopoll maps show the distributions of spruce (*Picea*), pine (*Pinus*), oak (*Quercus*), herb (nonarboreal pollen groups excluding Cyperaceae), and birch + maple + beech + hemlock (*Betula, Acer, Fagus, Tsuga*) pollen at specified times from 11,000 BP to present. Difference maps were constructed by subtracting successive isopoll maps and illustrate the changing patterns of pollen abundances from one time to the next. The isochrone maps portray the movement of ecotones and range limits by showing their positions at a sequence of times during the Holocene. After 11,000 BP, the broad region over which spruce pollen had dominated progressively shrank as the boreal forest zone was compressed between the retreating ice margin and the rapidly westward and northward expanding region where pine was the predominant pollen type. Simultaneously, the oak-pollen-dominated deciduous forest moved up from the south and the prairie expanded eastward. By 7000 BP, the prairie had attained its maximum eastward extent with the period of its most rapid expansion evident between 10,000 and 9000 BP. Many of the trends of the early Holocene were reversed after 7000 BP with the prairie retreating westward and the boreal and other zones edging southward. In the last 500 years, man's impact on the vegetation is clearly visible, especially in the greatly expanded region dominated by herb pollen. The large scale changes before 7000 BP probably reflect shifts in the macroclimatic patterns that were themselves being modified by the retreat and disintegration of the Laurentide ice sheet. Subsequent changes in the pollen and vegetation were less dramatic than those of the early Holocene.

A.A.

73. **BERRY, M.O. 1981. Recent changes in temperature, and comments on future climatic change. In: Climatic Change in Canada 2. Edited by: C.R. Harington. Syllogeus 33:19-27.**

By the early 1980s, it became apparent that a significant cooling of the Northern Hemisphere had occurred over the previous two decades. A number of apparently anomalous climatic events with major negative repercussions were also recorded.

The objective of this analysis is to examine recent trends in temperature in Canada, and to look at some recent climatic events from a longer-term perspective.

In summary, has Canada really become cooler in the 30 years from 1949 to 1978? The eastern half of the country was colder by 1969-78 than in the decade starting in 1949, with the cooling trend in most areas (the Lower Great Lakes, Upper Saint Lawrence and Maritimes being exceptions) intensifying from the second to last decade of the period. In contrast much of the western half of the country was warmer by the third decade, the main exception being an area of cooling in northern British Columbia and part of the Yukon.

Excerpts

74. **BERTI, A.A. 1975. Paleobotany of Wisconsinan interstadials, eastern Great Lakes region, North America. Quaternary Research 5(4):591-619.**

This study concerns the pollen and plant macrofossils from Mid-Wisconsinan Interstadial sites within the Wisconsinan ice margin in eastern North America. The time period covered is from about 55,000 years BP to 22,500 years BP, an interval much longer than the postglacial. Sediments examined are principally those of large lakes deposited in the Erie and Ontario basins during intervals of ice retreat.

The Port Talbot I Interval (from about 55,000 to 50,000 years BP) in the Erie basin is characterized by pollen assemblages alternating from *Pinus*-dominated zones to one with abundant *Pinus*, *Quercus*, and nonarboreal pollen. These assemblages are interpreted as indicating relatively warm and dry conditions. Mean July temperatures fluctuated between 15 and 21°C.

During the succeeding Port Talbot II Interval and Plum Point Interstadial, in both the Erie and Ontario basins, pollen assemblages are characterized by dominant *Pinus* and *Picea*. Characteristic macrofossils include needles of the boreal *Picea* and *Larix* and leaves of species with a more northerly distribution, such as *Dryas integrifolia, Betula glandulosa* var. *glandulosa, Vaccinium uliginosum* var. *alpinum*, and *Salix herbacea*. These fossil assemblages are interpreted as indicating cooler and moister conditions in a forest-tundra environment. Mean July temperatures fluctuated between 10 and 15°C during the Port Talbot II Interval and Plum Point Interstadial.

A.A.

75. BESCHEL, R.E. 1961. Dating rock surfaces by lichen growth and its application to glaciology and physiography (lichenometry). In: Geology of the Arctic, vol. II. Edited by: G.O. Raasch. University of Toronto Press, Toronto. pp. 1044-1062.

Most of the arctic and alpine crust lichens, especially the genera *Rhizocarpon* and *Lecidea* grow very slowly. This can be concluded indirectly from maximum diameters on rock surfaces of known age or repeated measurements. The over all constant increment after an initially sigmoidal growth allows dating of rock surfaces exposed up to 1000-4500 years BP, depending on the climatic conditions. Lichenometry permits relative dating of events which led to the exposure of bare rock surfaces within the age limit of the lichens in similar macroclimates. This can be converted to an absolute scale if one event is dated by other means, e.g. historical information, or if the growth rate is measured directly. From lichen measurements obtained in West Greenland, the Alps, and the Ruwenzori Mountains, the synchronism of glacier behaviour within the advance period of modern times (400-40 BP) appears very high. Early hypothermal moraines and boulder streams can be separated clearly from early modern ones, even if other morphological criteria fail.

Lichen growth rates are inversely proportional to the hygrocontinentality of the area. This permits calculation of this or similar combined climatic factors through lichenometry, or the prediction of lichen growth rates from the known climate.

Lichenometry is especially useful where dendrochronology is impossible.

A.A.

76. BIK, M.J.J. 1968. Morphoclimatic observations on prairie mounds. Zeitschrift für Geomorphologie 12(4):409-469.

Descriptively, the parent form of the present day prairie mound of the Foremost-Cypress Hills area of southern Alberta approximated a cone and crater in shape, and had greater relief; it has been substantially "smoothed" by a sequence of morphogenetic events occurring over the last 10,000 years or so; the central depression as well as major and minor breaches of the rim are an integral part of the parent form; an explanation of its origin should address itself to these characteristics, an aspect taken up in another paper (Bik, 1967).

The Allerod Period is represented in the central fill of the mounds through cessation of niveo-aeolian deposition and colonization with *Stagnicola palustris* (Muller) (and presumably other species). During this period, the climate was semi-arid, perhaps comparable to the present day conditions in the Foremost-Cypress Hills area. Bedded niveo-aeolian deposits are tentatively assigned to the Earlier Dryas Period, in which periglacial conditions appear to have occurred in southern Alberta. An upper niveo-aeolian deposit, that post-dates the Allerod was tentatively placed in the Younger Dryas Period. Initially dry periglacial conditions changed to moister, cold conditions, since solifluction becomes more dominant and niveo-aeolian advection less important as time advances. Soil formation preceded the later niveo-aeolian phase and quite likely marks the Allerod Period in dated sedimentary sections further west.

Slope stability and soil formation followed the second periglacial phase of landscape development and was terminated with the deposition of a thin layer of volcanic ash. Slope instability, quite likely under more arid climatic conditions than occur in the area at the present time, produced thick colluvial deposits. This phase of slope instability is tentatively placed in the Xerothermal, on the basis of an analogy with the sequence of deposits in the Waterton Park area. The volcanic ash most likely represents the Mazama ash fall.

The superficial stone cover, a common characteristic of the larger prairie mounds of the Foremost-Cypress Hills area of southern Alberta, resulted from degradation of the higher slope segments of the mound rims; it developed during the deposition of the colluvium that rests on the volcanic ash, and may date from the Xerothermal Period. Deposition of this colluvium occurred in two stages interupted by a phase of erosion, which removed the matrix and resulted in a residual stony horizon. Cessation of colluvial deposition cannot be assigned an age since no *"ante quem"* date is available for these deposits.

A.C.

77. **BIRKS, H.J.B. 1979. The use of pollen analysis in the reconstuction of past climate: a review. International Conference on Climate and History, University of East Anglia, Norwich, July 8-14, Review Papers. pp. 5-28.**

Pollen analytical data obtained from lake and bog sediments provide direct information relevant to the reconstruction of the past flora and vegetation of the area under study. As both modern floras and modern vegetation are related in a broad way to modern climate, pollen analysis can provide indirect information relevant to the reconstruction of past climates over particular time spans (1000-10000 years) with a sample resolution of 100-500 years.

Various approaches are available in reconstructing past climates from palynological data. The floristic or 'indicator-species' approach is reviewed, in which the modern distributions of particular species are compared with contemporary climatic patterns. Limitations of this approach are considered in the light of recent experimental studies on the climatic tolerances of selected species of contrasting distributions. Studies involving the distribution and performance of a few selected species in relation to two or three ecologically important climatic variables are also discussed. The vegetational or 'multivariate' approach is described in which modern transfer functions are used to calibrate modern pollen assemblages in terms of modern climate. These functions are then used to transform fossil pollen data into quantitative estimates of past climate. Various refinements to this approach are considered, and the advantages, disadvantages, and assumptions of the approach are discussed.

A.A.

78. **BLAKE, W., Jr. 1964. Preliminary account of the glacial history of Bathurst Island, Arctic Archipelago. Geological Survey of Canada Paper 64-30:1-8.**

Bathurst Island, in the central part of the Arctic Archipelago, lacks the prominent glacial landforms such as drumlins and eskers that characterize certain more southerly islands. It does not appear to have been overridden by the continental North American (Laurentide) ice sheet during the last glaciation (classical Wisconsin). Nonetheless Bathurst Island bears undoubted evidence of glaciation in the form of till, erratics, and meltwater channels. Erratics, commonly of a quartzose sandstone that outcrops on the island, are widespread and occur at altitudes up to at least 1,100 feet (335 m), far above the limit of marine submergence. Other important features indicating glaciation are: striae, lakes in bedrock basins, areas of streamlined drift, end moraines, and areas of dead-ice topography.

Apparently most of these features are related to locally-centred ice cap(s), but the occurrence of till containing shells above the marine limit at several localities along the east coast may possibly be the result of a glacier tongue in the straits having impinged upon the island.

The rapid uplift that has taken place in postglacial time, as determined by radiocarbon dating of marine shells from the raised beaches, is believed to have resulted from glacial rebound. Thus the last glaciation of Bathurst Island is inferred to have taken place during Wisconsin time. The altitude of the marine limit is close to 300 feet (90 m) along the east central and southeast coasts, but it reaches 400 feet (120 m) in the long inlets that indent the north coast, suggesting that the ice may have been thicker in the latter area.

The radiocarbon dates on marine shells, plus one on peat, also indicate that much of the island was ice-free by 9,000 years ago. Since then peat deposits have formed in many localities, but in two places buried peats are more than 35,000 years old, suggesting that they are interglacial, or possibly interstadial, in age.

A.A.

79. BLAKE, W., Jr. 1966. End moraines and deglaciation chronology in northern Canada with special reference to southern Baffin Island. Geological Survey of Canada Paper 66-26:1-31.

An extensive system of end moraines near Frobisher Bay and on Foxe Peninsula, in southern Baffin Island, are described for the first time. The section crossing Frobisher Bay can be traced for some 325 miles (525 km). The high level "strandlines" described from the southwest side of Frobisher Bay by several workers are in reality a combination of kame terraces, lateral moraines, and marginal lake terraces—all related to the moraine system and formed beside a major ice lobe entering Frobisher Bay from the northwest.

Numerous radiocarbon dates show that: 1) ice from Hudson Strait impinged on the south coast of Baffin Island during the last glaciation, carrying marine shells far above the level of marine submergence; 2) all or nearly all of Hudson Strait was filled by ice 9,000 years ago, but was ice free by 8,000 years ago, and the sea had reached the limit of submergence south of James Bay a short time after 8,000 years BP; 3) the major moraines crossing Frobisher Bay, near Rae Isthmus at the south end of Melville Peninsula, and at MacAlpine Lake, District of Mackenzie, were forming some 8,200 years ago, but parts of the moraine system in northern Baffin Island probably formed earlier; 4) moraine formation continued for several hundred years after 8,200 BP; 5) innermost Frobisher Bay and Foxe Basin were ice free by 6,900 to 6,700 years ago; and 6) Amadjuak Lake was free of ice before 4,500 BP, although the last mass of ice, which lay northeast of this lake, may have still been in existence then.

The orientation of the moraines in southern Baffin Island and radiocarbon dates from widely spaced areas in northern Canada show the need for reappraisal of the "Cockburn Glacial Phase" hypothesis and the postulated position of the ice-edge 9,500 or 9,000 to 8,000 years ago (cf. Falconer *et al.*, 1965a, 1965b).

A.A.

80. BLAKE, W., Jr. 1970. Studies of glacial history in Arctic Canada. I. Pumice, radiocarbon dates, and differential postglacial uplift in the eastern Queen Elizabeth Islands. Canadian Journal of Earth Sciences 7(2):634-669.

Dark brown pumice has been discovered recently on raised beaches of Ellesmere and Devon Islands, and in archeological sites on Baffin Island. It is similar in appearance and chemical composition to pumice associated with raised marine features throughout northern Europe, especially along the coasts of Norway and Spitsbergen. The source area for the pumice is uncertain, but Iceland is a good possibility.

Radiocarbon dates on driftwood and whale bones embedded in beaches at the "pumice level", as well as at higher and lower elevations, indicate that the pumice arrived approximately 5000 years ago.

The pumice serves as a time-line and provides a means of correlating widely-separated marine features. Because these features now occur at different elevations, the amount and direction of tilt can be calculated. Also, former ice centers can be delineated, as the areas which have undergone the greatest uplift are those where the ice cover was once thickest. In Arctic Canada the "pumice level" rises westward along Jones Sound, from 16.5 m a.s.l. at the mouth of South Cape Fiord, Ellesmere Island, to 24.5 m at the eastern tip of Colin Archer Peninsula, Devon Island, ca. 130 km away. It also rises northwestward toward the head of South Cape Fiord.

The Jones Sound information, plus radiocarbon dates from elsewhere in the Queen Elizabeth Islands indicating the approximate position of the shoreline at the same time, shows that there is a region in the eastern and central part of the archipelago where >25 m of uplift has occurred during the last 5000 years. This region, including considerable areas that are now sea, is believed to have been covered by a major ice sheet during the last glaciation.

A.A.

81. **BLAKE, W., Jr. 1972. Climatic implications of radiocarbon-dated driftwood in the Queen Elizabeth Islands, Arctic Canada. In: Climatic Changes in Arctic Areas During the Last Ten-thousand Years. Edited by: Y. Vasari, H. Hyvärinen and S. Hicks. Acta Universitatis Ouluensis Series A, Scientiae Rerum Naturalium 3, Geologica 1:78-104.**

Numerous radiocarbon dates show that by 10,000 years ago the disintegration of the Innuitian Ice Sheet was well underway in the western part of the Queen Elizabeth Islands, although a lobe of the Laurentide Ice Sheet still impinged on the south coast of Melville Island at that time. By 8,000 years ago all of the inter-island channels were open, with the possible exception of the northern part of Nares Strait between Ellesmere Island and Greenland. The oldest driftwood logs discovered, from widely separated parts of the archipelago, are between 8,500 and 8,000 years old. Driftwood 6,500 to 4,500 years old is especially abundant, indicating that at least as much open water as at present, and probably more, existed during that interval. The marked decrease in the abundance of driftwood between approximately 4,500 and 500 years BP is attributed to the onset of more severe sea ice conditions, an event which coincided with the development of ice shelves, especially along the north coast of Ellesmere Island, but perhaps elsewhere in the archipelago as well.

A.A.

82. **BLAKE, W., Jr. 1973. Former occurrence of *Mytilus edulis* L. on Coburg Island, Arctic Archipelago. Naturaliste Canadien 100(1):51-58.**

Investigations on Coburg Island, Arctic Archipelago, have revealed that the blue mussel, *Mytilus edulis* Linné, formerly lived 350 km north of its present limit. The age of the mussels on Coburg Island is >38,000 radiocarbon years (GSC-1425), and the deposit probably relates to the warm interval, with accompanying higher sea-level, which corresponds to the Sangamon Interglacial of continental North America.

A.A.

83. **BLAKE, W., Jr. 1974. Periglacial features and landscape evolution, central Bathurst Island, District of Franklin. Geological Survey of Canada Paper 74-1B:235-244.**

While carrying out a reconnaissance of the surficial geology of Bathurst Island in 1963, a number of observations were made of periglacial features, especially those which occur along the low, central valley which crosses the island. Much of the 1963 field season, as well as June 1964, was devoted to collecting samples of terrestrial and marine materials for radiocarbon dating, in order to establish a chronology of events bearing on the glacial history of the island (Blake, 1964, 1974).

Close to 8500 years ago the sea filled Polar Bear Pass, which now does not exceed 100 feet (30 m) in elevation, to a depth of more than 150 feet (46 m). As the land rose relative to the sea, because of isostatic rebound following removal of the ice load, features such as the beach ridges shown in Figures 4 and 5, were cut at successively lower elevations; the particular ones illustrated, above the 200 foot (60 m) level, are close to 8000 years old. On the other hand, the uppermost layer of *Mya truncata* shells exposed in a section along the Caledonian River at the western end of Polar Bear Pass is 4750 ± 140 years old (GSC-783; Blake, 1970; Lowden *et al.*, 1971), and sea level at the time these molluscs were living was an unknown amount above the level at which they now occur, ca. 75 feet (23 m). This is approximately the same elevation as that of the largest lake now occupying Polar Bear Pass (Figure 1), indicating that this through valley persisted as an arm of the sea until nearly 4500 years ago.

Excerpts

84. BLAKE, W., Jr. 1974. Studies of glacial history in Arctic Canada. II. Interglacial peat deposits on Bathurst Island. Canadian Journal of Earth Sciences 11(8):1025-1042.

Sixteen radiocarbon age determinations on peat deposits and buried organic layers at 10 localities within the Queen Elizabeth Islands have resulted in ages between >30,000 and 51,000 years. Similar results have been obtained from the southern Arctic islands, and as yet only one meaningful finite date in the 50,000 to 25,000 year-range has resulted from the dating of driftwood or *in situ* terrestrial organic materials in the entire archipelago.

On Bathurst Island, where two dates of >50,000 years have been obtained, evidence from the assemblages of mosses, vascular plants, and insects in peat and organic layers indicates that climatic conditions were somewhat more favorable than at present when these deposits were forming. The available data are such that all deposits cannot necessarily be related to the same non-glacial interval, but the extensive deposits along the Stuart River are poorly assigned to the Stuart River Interglaciation.

The lack of organic materials dating between 50,000 and 25,000 years in the Queen Elizabeth Islands may be because: (1) the area was ice-covered throughout Wisconsin time; (2) any mid-Wisconsin non-glacial interval was too short or had too severe a climate for deposits to accumulate; (3) organic deposits relating to this interval have been eroded; (4) or deposits of this age do exist but they have not been collected.

A.A.

85. BLAKE, W., Jr. 1975. Radiocarbon age determinations and postglacial emergence at Cape Storm, southern Ellesmere Island, Arctic Canada. Geografiska Annaler 57A(1-2):1-71.

Age determinations on marine mollusks indicate that the northwestern part of Jones Sound became open to the sea more than 9000 conventional radiocarbon years ago. The presence of postglacial marine features at elevations of up to 130 m near Cape Storm, Ellesmere Island, shows that a significant thickness of glacial ice was present in this area, and the differential uplift of pumice and other materials associated with raised beaches provides convincing evidence that the former ice cover was thicker to the west and to the north.

Near Cape Storm over fifty ^{14}C age determinations on driftwood, whale bone, and marine mollusks have permitted the construction of a curve showing the pattern of emergence over the past 9000 to 9500 years. Emergence between 9000 and 8000 years ago proceeded at a rate of 7 m/century, and over one-half of the total emergence (70 m out of 130 m) since the initial incursion of the sea took place during this interval. By 6500 to 4500 years ago emergence had slowed to 0.8 m/century, and for the last 2400 years it has averaged <0.3 m/century. The age determinations are sufficiently numerous and closely-spaced, especially between 6500 and 4400 years BP, to indicate that fluctuations of sea level have not exceeded amplitudes of 2 m or periods >500 years. The concentration of the pumice and the nature of the features associated with it suggest that its deposition may be related to: 1) a eustatic rise close to 5000 years ago; 2) a period of more open water, when wave action and storm surges would have been more effective; 3) a combination of these two factors. The formation of the strandline where the pumice occurs is not believed to be related to a slowing-down or cessation of uplift due to the thickening of ice caps and glaciers.

pA.A.

86. BLAKE, W., Jr. 1976. Glacier ice cores, climate, and chronology around northern Baffin Bay. American Quaternary Association, 4th Biennial Meeting, Abstracts:20-21.

Methods of deriving a time scale from glacier ice cores, such as those recovered from Camp Century, Greenland, and from Devon Island, are among the topics discussed by Paterson in his Abstract for this AMQUA session. My contribution is intended to summarize the available chronological evidence from land areas around northern Baffin Bay, because the chronology of events deduced from the ice cores must accommodate the marine and terrestrial record as to when nearby areas were glacierized and when they were ice-free.

Sections exposed in widely separated localities - at Cape Storm, southern Ellesmere Island, on Coburg Island (at the mouth of Jones Sound) and on Saunders Island (northwestern Greenland) - display a similar stratigraphic succession. The oldest Holocene marine strata were deposited close to 9000 radiocarbon years ago, although the postglacial marine incursion may have reached some localities by 10,000 years BP. Critical dates are: 9330 ± 110 years (GSC-1415; 100.5 m a.s.l.) at Cape Storm, 8940 ± 10 years (GSC-1426; 7 m a.s.l.) on Coburg Island, and 8970 ± 100 years (GSC-2210; 13 m a.s.l.) on Saunders Island. These age determinations are in agreement with others around northern Baffin Bay; e.g., molluscs at Cape Tennyson, southeastern Ellesmere Island, are 9040 ± 90 years old (GSC-1058; 30 m a.s.l.). The fossiliferous strata are underlain by beds, till-like in places, which do not contain marine molluscs; these beds are believed to have been deposited during a glacial episode. Marine molluscs are present beneath the non-fossiliferous units at each site, and on Coburg and Saunders Islands the fauna is characterized by the presence of *Mytilus edulis* L. This mussel, although it now lives in these high latitudes along the Greenland coast, is not known to occur north of Baffin Island in the Canadian Arctic Archipelago. Age determinations indicate that the *Mytilus*-bearing beds are >38,000 years old (GSC-1425) on Coburg Island and >40,000 years old (GSC-2143) on Saunders Island; the uppermost dated molluscs in the strata underlying the till-like unit at Cape Storm are >34,000 years old (GSC-2209).

Paterson also has cited reasons why changes in the oxygen isotope ratios (δ) with depth cannot be equated directly with changes in temperature. However, the time scale for changes in δ, as derived by Dansgaard and co-workers, is in good general agreement with the chronology derived from radiocarbon dating of marine molluscs on nearby coasts:

1. The faunal composition and the nature of the strata above the *Mytilus*-bearing horizons suggest that environmental conditions as favourable as during the Holocene have not existed for a period of time exceeding 40,000 years; the same conclusion is implied by the δ record.

2. A pronounced change in δ is indicated as having occurred between 13,000 and 10,000 years BP. The evidence from the marine fauna in no way contradicts the hypothesis that this was a period of warming, during which large volumes of ice were being removed, and that the incursion of the sea onto the existing islands (areas now above sea level) took place between 10,000 and 9000 years ago.

3. In the Camp Century core the maximum values of δ during the Holocene occur between 6000 and 5000 years BP. This coincides with the period, as determined by the distribution of ^{14}C-dated driftwood, during which there was apparently a less extensive cover of sea ice in the Canadian Arctic Archipelago. It is also the time when the ice shelf fringing the northern coast of Ellesmere Island was much less extensive, if in fact it existed at all.

A.A.

87. BLAKE, W., Jr. 1978. Aspects of glacial history, southeastern Ellesmere Island, District of Franklin. Geological Survey of Canada Paper 78-1A:175-182.

Field work around Makinson Inlet, Ellesmere Island, has revealed that erratics, striated rock surfaces, and marginal drainage channels are widespread. These features, plus the glacial sculpture on Bowman Island, show that a major outlet glacier formerly flowed eastward in Makinson Inlet, draining a significant mass of ice that lay to the west of the present-day ice caps. A fossil peat deposit indicates an ice-free interval >44,000 years (GSC-140-2) ago with a climate more favourable than that of the west today. During Holocene time the sea penetrated to the head of the west arm of Makinson Inlet by 8930 ± 100 years BP (GSC-2519) and to the head of the north arm by 7330 ± 80 years BP (GSC-1972).

A.A.

88. BLAKE, W., Jr. 1981. Neoglacial fluctuations of glaciers, southeastern Ellesmere Island, Canadian Arctic Archipelago. Geografiska Annaler 63A(3-4):201-218.

Two new series of radiocarbon age determinations form the basis for this paper. The first series shows that both the outer east coast of Ellesmere Island (north to latitude 78°36') and much of Makinson Inlet were free of glacier ice prior to 9000 radiocarbon years ago (dates uncorrected for the apparent age of sea water). However, on the basis of the available data the head of the north arm of Makinson Inlet, north of the present site of Split Lake, was not invaded by a marine fauna until about 2000 years later, presumably because of the persistence of glacier ice in this trough.

The second series of age determinations relates to fluctuations of outlet glaciers during Holocene time. Dates of 5180 ± 260 years (GSC-2909) and 2590 ± 150 years (GSC-3191) for the bottom and top, respectively, of a massive peat deposit bracket a period during which outlet glacier 7A-45, north of the head of Makinson Inlet, was smaller than it is at present. Data from several sites suggest an advance of glaciers about 1000 years ago, and a second advance, during the last 100 years or so, is recorded at the margins of a number of glaciers draining the ice caps in central and southeastern Ellesmere Island.

A.A.

89. BLAKE, W., Jr., and J.V. MATTHEWS, Jr. 1979. New data on an interglacial peat deposit near Makinson Inlet, Ellesmere Island, District of Franklin. Geological Survey of Canada Paper 79-1A:157-164.

Examination of peat samples collected in 1977 near Makinson Inlet has revealed the presence of fossils of *Andromeda polifolia* and *Menyanthes trifoliata*, plants which do not live in the Arctic Islands today. Likewise, fragments of the ground beetle *Amara alpina* and the ladybird beetle *Nephus georgei*, neither of which occurs as far north today, are present. The occurrence of these fossils beyond their present limits, coupled with the fact that the uppermost layer of peat in the deposit is >52 000 years old (GSC-2677), suggests that the peat is an interglacial deposit.

A.A.

90. BLASING, T.J., and H.C. FRITTS. 1975. Past climate of Alaska and northwestern Canada as reconstructed from tree rings. In: Climate of the Arctic. Edited by: G. Weller and S. Bowling. 24th Alaska Science Conference, University of Alaska, Fairbanks. pp. 48-58.

Spatial anomaly patterns of sea-level pressures over North America, the North Pacific, and eastern Asia in the 20th century can be statistically calibrated with spatial anomaly pattern of tree growth in semi-arid western North America. Growth anomalies prior to 1900 were substituted into the calibration equations to reconstruct past circulation features for the 18th and 19th centuries. The success of the reconstructions for the Arctic was tested against climatic data where possible and against the variations in growth of Arctic trees which respond to variations in climate. Ten different types of tree-growth anomaly pattern were identified in the Arctic between 1800 and 1939. Tentative Arctic trees were compared to circulation anomalies over the Arctic as reconstructed from the arid-site trees to the south. Both of these sources of information were used to infer climatic conditions for the period 1800-1939. Tentative inferences are presented as to climatic conditions for each of five regions in Alaska and northwestern Canada in hope that they may be tested against other lines of evidence.

A.A.

91. BLISS, L.C. 1975. Devon Island, Canada. In: Structure and Function of Tundra Ecosystems. Edited by: T. Rosswall and O.W. Heal. Ecological Bulletin (Stockholm) 20:17-60.

The author conducted an investigation of the Truelove Lowland located along the northeast coast of Devon Island to determine "energy flow through the system and its major components."

"Much of the island was deglaciated 8,700 years B.P. These coastal lowlands result from postglacial rebound following deglaciation. Radiocarbon dating has shown that the upper marine limit is at 76 m, dating to ca. 9,450 B.P.

"Due to the shallow nature of peats in the Lowland, it is difficult to obtain Post-Wisconsin paleobotanical information. Cores taken to a depth of 170 cm in the raised center of an ice-wedge polygon contained thin peat horizons. The basal peat in this locality was radiocarbon dated by Barr to be 2,450 ± 9 years. The pollen spectrum is poor quantitatively and qualitatively. Pollen of *Salix arctica* Pall., Cyperaceae, and Poaceae is most numerous and shows no major shift in importance with depth. The spectrum corresponds qualitatively to present vegetation.

"Macrofossil plant remains were well preserved throughout the profile. Mosses, rich in species diversity predominate but with considerable amounts of *Salix* and *Dryas* leaves and twigs below 125 cm. No seeds or fruits were found, probably the result of low production and their harvest by birds and lemming. The limited data do not permit an evaluation of oscillating climate as has been possible in Greenland and northern Ungava."

Excerpts

92. BOER, G.J., and K. HIGUCHI. 1981. Climatic variability in the northern hemisphere. First Conference on Climate Variations of the American Meterological Society. Jan. 19-23, 1981, San Diego. Abstracts, p. 8.

An analysis of variance of the 1000-500 mb thickness field is performed to investigate climatic variability from 1949-75. The thickness field and the transient eddy, standing eddy and north-south variances, averaged over the Northern Hemispheric cap from 25°N to the pole, are obtained on a monthly basis.

The resulting time series are analyzed to their trends and interrelationships. This study is an outgrowth of a previous study on this subject. In this study, the long-term trends (or lack thereof) in the variability measures are investigated on a monthly and seasonal basis.

A.A.

93. BOLIN, B. 1975. Energy and Climate. Stockholm University for Secretariat for Future Studies. 58 pp.

Topics dealt with include climatic changes since the last glaciation, some aspects of the general circulation of the atmosphere and its importance on the distribution of climatic zones on the earth, energy fluxes in the climatic system, climatic changes and their possible causes, and possible future climatic changes caused by an increasing energy production.

G.A.

94. BOMBIN, M., and C. SCHWEGER. 1978. Silicophytoliths as paleoecological indicators to the reconstruction of the late Pleistocene steppe-tundra of the Yukon Territory, Canada. American Quaternary Association, National Conference, Abstracts 5:187.

Most plants contain opaline silica bodies deposited in cells or intercellular spaces particularly in the leaves, but diagnostic morphotypes appear to be more common among the Mono-cotyledons. These silicophytoliths ... are generally well preserved in sediments and soils, to a greater extent than pollen. Silicophytoliths are widely deposited in leaves, inflorescences and roots of the Gramineae; they display nearly constant morphology, with taxonomic specificity suggested at least at the level of genera, although no complete studies on species assemblages have been made. Different grasses display overlapping morphotypes making discrimination in the fossil assemblage a very difficult task.

Phytolith analysis is a promising technique in taxonomy and paleoecology, but the lack of descriptive information on morphology and species morphotypes frequencies has limited its application.

The first author is engaged in a research project to formalize phytolith analysis, and at the same time apply the method to interpretation of Late Pleistocene sequences in the Yukon Territory, using reference collections in preparation and assemblages representing present day environments. During the late glacial, unglaciated areas of the Yukon have been characterized as arctic grassland steppe or steppe-tundra, evidenced by high percentages of *Artemisia*, Cyperaceae and Gramineae pollen. Since the two latter families cannot be distinguished further, there is a great need for application of another paleoecological method. Identification of grass, sedge and herbaceous cover to at least the generic level, using silicophytolith analysis, would allow comparisons with extant northern grasslands, particularly the so called "relic steppes." This work should provide proxy data for paleoclimatic inferences, pedology, paleopedology, permafrost and stratigraphic correlation.

Field research will concentrate on stratigraphic exposures in the Old Crow-Porcupine Basin.

pA.A.

95. BORISENKOV, E.P. 1975. Energetics estimation of climatic trends in the present century. In: Long-term Climatic Fluctuations, World Meteorological Organization, Geneva WMO-421:269-278.

The energetics principle of estimation and interpretation as a method of analysing the climatic trends of the past century are discussed.

G.A.

96. BORNS, H.W., Jr., and R.P. GOLDTHWAIT. 1966. Late-Pleistocene fluctuations of Kaskawulsh Glacier, southwestern Yukon Territory, Canada. American Journal of Science 264(8):600-619.

The 45-mile-long Kaskawulsh is one of many outlet glaciers draining the glacier-filled coastal Icefield Ranges into the dry interior of the Yukon Territory. Its deposits express the major climatic changes of the last 10,000 years. A great retreat, many miles up valley from the present terminus, occurred 12,000 to 9,000 years ago leaving drift clinging to valley walls and completed alluvial fans. Winds over the active valley train added up to 8 feet of loess (Kluane loess) on these deposits and buried 9,700-year-old vegetation near the present glacier terminus. During the Slims nonglacial interval (essentially the Hypsithermal interval) weathering developed a bright red-yellow paleosol (Slims Soil) in this loess. In the lower parts of a bog, just above the Neoglacial terminal moraine, there are dominant grass pollen and moss spores which suggest a wetter climate than today. But just above the 3300-year-old date in this bog, peat with sedge, spruce, and Artemisia pollen show a marked change to a drier climate like that of today. In addition, a new unweathered loess (Neoglacial loess) covers the red-yellow paleosol and 2600-year-old vegetation. The climatic change and reactivated outwash signal the Neoglacial advance 2600 to 3000 years ago.

Kaskawulsh Glacier reached its terminal position, where it left a prominent loop moraine, by approximately 300 years ago (C^{14} dates) and was there as late as 145 years ago when it bent over a spruce tree with countable rings. Halting retreat for the last century has left two ice-cored loop moraines: the older one completely formed in 1939.

A.A.

97. BORNS, H.W., Jr., and T.J. HUGHES. 1977. The implications of the Pineo Ridge readvance in Maine. Géographie physique et Quaternaire 31(3-4):203-206.

Much of the Laurentide ice sheet in Maine, Atlantic Provinces, and southern Quebec was a "marine ice sheet", that is it was grounded below the prevailing sea level. When proper conditions prevailed, calving bays progressed into the ice sheet along ice streams partitioning it, leaving those portions grounded above sea level as residual ice caps. At least by 12,800 yrs BP a calving bay had progressed up the St. Lawrence Lowland at least to Ottawa while a similar, but less extensive calving bay developed in central Maine at approximately the same time. Concurrently, ice draining north into the St. Lawrence and south into the Central Maine calving bay rapidly lowered the surface of the intervening ice sheet until it eventually divided over the NE-SW trending Boundary and Longfellow Mountains and probably over other highland areas as well. A major consequence of these nearly simultaneous processes was the separation of an initial large ice cap over part of Maine, New Brunswick, and Quebec which was bounded on the west by the calving bay in Central Maine, to the north by the calving bay in the St. Lawrence Lowland, to the south by the Bay of Fundy, and to the east by the Gulf of St. Lawrence. In coastal Maine, east of the calving bay, the margin of the ice cap receded above the marine limit at least 40 km and subsequently readvanced terminating at Pineo Ridge moraine approximately 12,700 yrs BP. These events are the stratigraphic and chronologic equivalent of the Cary-Pt. Huron recession/Pt. Huron readvance of the Great Lakes region.

Although a great deal more research is necessary the chronology and significance of these events when combined suggest a hemispheric climatic pattern including "cold" periods roughly between 13,000 and 12,000 yrs BP and between 11,000 and 10,000 yrs BP separated by a "warm" period from approximately 12,000 to 11,000 yrs BP.

A.A.+

98. BOULTON, G.S., J.H. DICKSON, H. NICHOLS, M. NICHOLS, and S.K. SHORT. 1976. Late Holocene glacier fluctuations and vegetation changes at Maktak Fiord, Baffin Island, N.W.T., Canada. Arctic and Alpine Research 8(4):343-356.

Maktak Glacier is a major distributary of the Penny Ice Cap and thus changes in its frontal position reflect variations in the mass balance of the ice cap. The Neo-glacial terminal moraine of this glacier consists of a 20-m thick sedimentary sequence of till, overlain by up to 18 m of sands and gravels which contain a 1-m thick peat bed. These sediments were deformed by glacier pushing and are overlain by a younger till. The basal till and the overlying sands and gravels beneath the peat were deposited during the retreat from the Cockburn Stade. The site was deglaciated at some time after 5000 to 6000 BP. Peat on a terrace surface was studied using "absolute" pollen analyses, and clustering routines to distinguish pollen zones. The start of peat growth at 2500 BP (synchronous with such events elsewhere) is attributable to altered permafrost levels and/or increases in precipitation/-evaporation budgets, producing wetter conditions locally. The vegetational history began with a moist willow episode, which was followed by a dominantly grass community as local conditions became drier. The initial rapid growth of peat conditions became progressively slower throughout the profile, until by 1500 BP the slow accumulation of humified peat was overwhelmed by windblown sand which inhibited further growth. A subsequent Maktak Glacier advance deposited sands and gravels over the peat bed. Between 350 and 65 BP, glacial pushing and overriding of the terrace and peat sediments occurred. Exotic tree pollens were identified in the sediments; their changing frequencies may provide some tentative measure of changing airflows into the High Arctic.

The eastern part of the Penny Ice Cap, as represented by the Maktak Glacier, may have a relatively simple Holocene history of post-Cockburn decline, growth after 4000 BP, and decline in recent decades. This contrasts with more complex response patterns of small cirque glaciers in the same areas. It is stressed that the data used in the paper cannot identify small-scale glacier oscillations.

A.A.

99. BOUSFIELD, E.L. 1961. Noteworthy records of marine molluscs from the Bay of Fundy. National Museum of Canada, Natural History Papers 10:1-3.

While visiting the coarse sand beach inside Partridge Island, south of Parrsboro, Nova Scotia, on July 22, 1958, the writer found three fragmentary valves of a heavy ark shell and eight partial valves of a strongly ribbed venerid clam.

On the assumption ... that the present molluscan material is subfossil, we may deduce probable conditions of water temperature and faunistic assemblages that formerly prevailed in that area. The presence of "Virginian" littoral marine molluscan and crustacean faunas in eastern Canada, separated from their present centres of distribution (Cape Cod to Cape Hatteras) by a large area of cold water (Gulf of Maine), has previously been attributed to one or more post-Pleistocene warm periods (e.g. Bousfield, 1956, 1958). Higher water temperatures would have been a logical result of lowered sea-levels and reduced tidal mixing, particularly in the northern part of the Gulf of Maine, immediately following the last ice advance. Conditions were evidently sufficiently warm not only to have permitted the continuous dispersal of Virginian faunas throughout the northern Gulf region, from which they are now all but excluded, but also to have invited the northward penetration of Carolinian elements into the Canadian Atlantic region. ... We may surmise, therefore, that temperature conditions in the Bay of Fundy may have formerly been analogous to those of present-day southern Chesapeake Bay and that the molluscan fauna included Virginian and Carolinian elements such as *Pecten irradians, Polinices duplicata, Donax fossor*, and *Busycon cannaliculata*, which may yet be discovered as fossils in the region.

Excerpts

100. BOUSFIELD, E.L., and M.L.H. THOMAS. 1975. Post-glacial changes in distribution of littoral marine invertebrates in the Canadian Atlantic region. In: Environmental Change in the Maritimes. Edited by: J.G. Ogden, III and M.J. Harvey. Proceedings of the Nova Scotian Institute of Science 27, Supplement 3:47-60.

In a series of seven coloured maps, the authors attempt to reconstruct summer surface temperatures for the Canadian Atlantic Coastal region (40°N-55°N, 45°W-80°W) in an effort to explain the present distribution of littoral marine invertebrates. In immediate post-Wisconsin time (15,000 BP) sea levels about 450 ft. below present, exposing all areas to the edge of the continental shelf. Climate was 5-10°C below present - still warm enough to provide a possible refugium for terrestrial, freshwater and intertidal arctic-boreal species on the unglaciated outer shelf margin. In early postglacial time (12,500 BP) continental ice was retreating rapidly inland and climate had waned to 5-10°C below present average levels. The coastal shelf was covered by a shallow sea studded with islands. During the early Hypsithermal period (9,500 BP), continental ice had withdrawn leaving a main ice cap in central Québec. Sea levels were rising rapidly but were still about 150 ft. below present on the outer coast, and climate was warming. In the mid-Hypsithermal (7,000 BP), mean temperatures were at least 2.5°C above present. Sea level rose to less than 100 ft. below present drowning many offshore islands. The warm-water fauna was continuous from southern New England to the Gulf of St. Lawrence. By 5,500 BP the climate was cooling and sea levels were less than 50 ft. below present. The warm-water fauna was being eliminated from outer coastal regions. By 3,000 BP the climate had cooled to nearly present levels, marked by short fluctuations. The warm-water fauna of the southern Gulf of St. Lawrence was isolated from that to the south.

C.R.H.

101. BOWERING, R. 1981. Impact of climate variability on water resources management. In: Climate Change Seminar Proceedings. Regina, March 17-19. Canadian Climate Centre, Downsview. pp. 28-32.

The importance of agriculture to Manitoba's economy, and the dependance of agricultural production on weather creates a direct link between the weather and Manitoba's economy. This paper will concentrate on variations from normal prairie weather patterns and will review the types of water resource problems which are caused by abnormal weather patterns, and discuss steps which can be taken to minimize some of these problems. Finally, the impact of a permanent climate shift will be briefly discussed.

There appears to be some evidence that the prairie climate is becoming more characterized by extremes, particularly in the short duration (minutes to days) and in the medium duration (a few months to a year) categories. During the years 1968, 1973 and 1977 there was virtually no winter snow accumulation or spring runoff. However in the adjacent years of 1969, 1974, and 1976, there was extremely heavy winter precipitation and extreme spring flooding. The 300 millimetre rainstorm in the Riding Mountain area in September, 1975 produced the first catastrophic fall flood in living memory in Manitoba. The 1980 drought in the Winnipeg to Portage la Prairie area was the worst in 100 years of record. This was followed by over 150 millimetres of rainfall in some parts of the Manitoba Interlake within a 24 hour period in the month of August, 1980. A good knowledge of climatic variability is an essential feature of an efficient water resource management system.

Excerpts

102. BOWLING, S.A. 1975. Possible significance of recent weather and circulation anomalies in northeastern Canada for the initiation of continental glaciation. In: Climate of the Arctic. Edited by: B. Weller and S.A. Bowling. 24th Alaska Science Conference, University of Alaska, Fairbanks. pp. 91-97.

The basic causes of climatic fluctuation between glacial and interglacial conditions remain debatable: On a purely phenomenological basis, though, deep-sea cores and ice-sheet cores strongly suggest the following: (i) Uninterrupted periods of temperatures near or above present levels have rarely exceeded 10,000-20,000 years in length. The Holocene has already lasted around 10,000 years. (ii) Interglacials such as the present tend to be interrupted by extremely rapid drops to near glacial conditions. Suggested time scales are less than 100 years for cooling, 1,000 years or more for recovery. In addition to the direct effects of a cold pulse, major redistribution of precipitation would occur, which could have drastic effects on agriculture.

Most theories are in agreement that the first observable signs of reformation of continental ice sheets would be an increase in the perennial snow cover in northeastern Canada and/or Scandinavia. Widespread perennial snow cover would affect the general circulation of the atmosphere in much of the same way as would a major ice sheet, with two exceptions. The orographic effect of an ice sheet would not be present, which could lead to even colder conditions in surrounding areas than would a true ice sheet. Also, a perennial snow cover which had not yet reached the ice sheet stage would be considerably less stable than a true ice sheet. Such a perennial snow cover could explain the observed brief cold pulses observed towards the end of previous interglacials. In terms of a human life span, of course, the distinction between a 1,000-year cold pulse and the beginning of a major ice sheet would be unnoticeable.

In the process of examining available climatological data for Labrador-Ungava, Keewatin and the northeastern Canadian islands, we found that monthly mean temperatures in these areas were not above normal (and were at times as much as 8°C below normal) from November, 1971 to February 1973. Investigation of 700 mb monthly mean maps since 1949 indicated that the 700 mb height at 65°N, 75°W was not significantly above normal for at least 18 months. Since the position 65°N, 75°W is approximately the center of the 700 mb low that has been proposed as part of an early glacial-age circulation, the recent weather anomalies in the United States and elsewhere may serve as a useful analogue to the climatic anomalies which could be expected in the early stages of a cold pulse.

A.A.

103. BOWMAN, P.W. 1931. Study of a peat bog near the Matamek River, Quebec, Canada, by the method of pollen analysis. Ecology 12(4):694-708.

Cores of peat were taken from a Quebec bog, and samples selected at 6-inch intervals were stained and mounted on slides for study. At least 1,000 spores were counted from each sample, and a record made of the number of each kind present. Curves were drawn to show the relative density of each kind of spore at each level. The curves show this to be an ocean type bog, with sedge present in the lower levels and *Sphagnum* in the upper. The curves also suggest that the bog went through an open marsh stage to one of closed forest. Each curve shows an individual trend and a set of secondary oscillations common to nearly all. ...we may estimate the greatest possible age of this bog to be under 2,500 years.

A.S.+

104. BOYKO-DIAKONOW, M., and J. TERASMAE. 1975. Palynology of Holocene sediments in Perch Lake, Chalk River, Ontario. In: Hydrological studies on a small basin on the Canadian Shield; a final summary of the Perch Lake evaporation study 1965-1974. Edited by: P.J. Barry. Atomic Energy of Canada, Report AECL-5041/I. pp. 189-220.

A sediment core, 785 cm in length, was collected from the western part of Perch Lake. Radiocarbon dating on a sample of gyttja from the 594-600 cm depth provided a date of 9,830 ± 250 years BP (GSC-1516). A palynological study was conducted, showing that Terasmae's pollen zones V-I were present.

When the Champlain Sea receded from the area vegetative cover was sparse, seeming to indicate a cold and moist climate. A warming trend with increasing drier conditions (perhaps seasonal) is suggested by the decrease in spruce and increase in white pine by about 9,500 years ago. By about 6,500 years ago species which today are typical of the Great Lakes - St. Lawrence forest (hemlock, beech, maple, oak, elm, birch and ash) appeared, suggesting a moister climate. This warm, moist climate continued for almost five millenia, becoming relatively very warm about 5,000 years ago as indicated by the sharp decrease in hemlock. The climate became colder about 1,000 years ago as beech, hemlock and maple pollen decreased.

A.B.S.

105. BRADLEY, R.S. 1973. Seasonal climatic fluctuations on Baffin Island during the period of instrumental records. Arctic 26(3):230-243.

Temperature and precipitation records for Baffin Island are examined on a seasonal basis for the last 40 to 50 years. Accumulation season temperatures (September to May) during the late 1960s were similar to those which prevailed 30 to 40 years ago. Ablation season temperatures (June, July, August) during the same period were cooler than for at least 30 years. Precipitation variations showed much less spatial coherence, but during the last 10 to 15 years there have been marked increases, mostly during winter months. These increases, accompanied by cooler summers and warmer winters, have led to increased glacierization of the area. The most recent fluctuation of summer temperatures is related to changes in the frequency of synoptic types in the area. Baffin Island is sensitive to small changes in climate which are only revealed by an analysis of temperature and precipitation on a seasonal basis.

A.A.

106. BRADLEY, R.S. 1973. Recent freezing level changes and climatic deterioration in the Canadian Arctic Archipelago. Nature 243(5407):398-400.

This paper presents "an analysis of upper air data for the Canadian Arctic Archipelago, which indicates that marked changes in freezing level heights have occurred during the past two decades as a result of changes in atmospheric circulation across the area." The critical change, as evidenced by the freezing level data, probably occurred around 1962-1964. For the past nine years, 1964-1972, July freezing levels have been much lower at all stations in the area. "A decrease in the elevation of the freezing level during summer months can ... greatly decrease the area of snow and ice affected by melting. ... The large changes in freezing level height since 1963 have produced significant glaciological responses in the Canadian Arctic."

A.B.S.

107. BRADLEY, R.S., and J. ENGLAND. 1978. Recent climatic fluctuations of the Canadian High Arctic and their significance for glaciology. Arctic and Alpine Research 10(4):715-731.

Various measures of the character of ablation season conditions in the Canadian High Arctic (north of 74°N) are discussed based on an analysis of daily climatic data from Alert, Eureka, Isachsen, Resolute, and Thule. Melting degree-day totals appear to be the most useful index of "summer warmth". An abrupt change in the summer climate of the region occurred around 1963/64. Various indices indicate a marked decrease in summer temperature after 1963. During the same period, annual precipitation in the north and northwest has increased.

Glacier mass is strongly controlled by summer climate; in particular, annual melting degree-day totals are highly correlated with long-term mass-balance records. This enabled mass balance on the northwest sector of the Devon Island ice cap to be reconstructed back to 1947/48. Cumulative mass losses on the Devon Island ice cap from 1947/48 to 1962/63 are estimated to be ~ 3500 kg m^{-2}. However, from 1963/64 to 1973/74 a total of <350 kg m^{-2} have been lost. Significant ice-cap growth is presently limited by low precipitation even when mean summer temperatures are very low; an occasional warm summer may therefore obliterate cumulative mass gains over many years.

The post-1963 change in summer climate appears to be related to the massive increase of volcanic dust in the upper atmosphere, primarily due to the eruption of Mt. Agung (March 1963). Subsequent eruptions may have caused the cooler conditions to persist. Volcanic dust affects solar radiation receipts and perhaps also influences the general circulation. If the high volcanic dust levels of the 1960s are responsible for reduced mass losses on High Arctic glaciers and ice caps, it is probable that other periods with high atmospheric dust levels (e.g., 1750 to 1880) had summer temperatures at least as cold as the mid to late 1960s. Conversely, the period of very negative balance on the Devon Island ice cap from 1947 to 1963 was probably typical of the period back to 1920 when the atmosphere was relatively free of volcanic dust.

A.A.

108. BRADLEY, R., and G.H. MILLER. 1972. Recent climatic change and increased glacierization in the eastern Canadian Arctic. Nature 237(5355):385-387.

This paper reports recent field work on Baffin Island, eastern Canadian Arctic, with an analysis of available climatic data for the area. Seasonal running means of temperature and precipitation for the major weather stations were calculated. "For the period 1960 to 1969 a marked decrease, by as much as 2.1°C, in the mean temperature of the ablation season (June to August) is apparent; but the accumulation season (September to May) shows an equally marked increase in temperature, by as much as 2.0°C." Two stations, at Cape Dyer and Frobisher Bay, are exceptions to this pattern and are a result of local conditions at each site. For the same 10-year period there have been marked increases of winter precipitation throughout

Baffin Island. The summer precipitation records exhibit greater station to station variability.

Airflow characteristics for July and August were studied. "From 1961-1965 to 1966-1970 there was a 29% increase in the number of days on which airflow with an easterly (particularly a north-easterly) component affected the region and a concurrent decrease in the number of days on which airflow with a westerly (particularly a south-westerly) component affected the region. The increased frequency of cool air being advected into the area from the east and north-east has apparently resulted in lower summer temperatures. A synoptic classification catalogue for all of the winter months is not yet available but it seems likely that the observed warming during these months is related to a higher frequency of days on which relatively warm, moist southerly air entered the region."

"Short term climatic changes are manifested visually, by field evidence, only in sensitive regions." Field observations (1969 to 1971) of permanent snowbanks, incipient glaciers, and the duration of ice cover on small lakes, were compared with aerial photographs taken late in the ablation seasons of 1949 and 1960. Support is given to the climatological evidence for a climatic deterioration. "During the past decade mean annual temperatures on Baffin Island have been increasing, but the net effect on the landscape is an apparent move towards more glacial conditions."

A.B.S.

109. BRAY, J.R. 1964. Chronology of a small glacier in eastern British Columbia, Canada. Science 144(3616):287-288.

The age of trees growing on the moraines of a small, high-altitude glacier in the Canadian Rockies suggests that the date of the maximum post-Pleistocene ice advance was around A.D. 1714, with another later advance about 1832. These two dates are synchronous with the two major periods of recent ice readvance in the area.

A.A.

110. BRAY, J.R. 1965. Forest growth and glacier chronology in north-west North America in relation to solar activity. Nature 205(4970):440-443.

During the period 1610-1964 for which sunspot observations are available, the great majority of advances of ice in north-west North America occurred at the close of and immediately following periods of low sunspot activity. Glacial retreat or stagnation occurred during periods of higher sunspot activity. Tree growth in the Yoho National Park area of British Columbia was positively correlated with sunspot activity during this period, which may reflect a relationship between growing season, climate and solar activity. There is also evidence, although fewer data are at present available, that glacial advance during the past several millenia has predominated in centuries of lower average sunspot activity, and glacial retreat and stagnation have predominated in centuries of higher average sunspot activity.

A.C.

111. BRAY, J.R., and G.J. STRUIK. 1963. Forest growth and glacial chronology in eastern British Columbia, and their relation to recent climatic trends. Canadian Journal of Botany 41(8):1245-1271.

Recent activity of Yoho Glacier was determined by botanical and geological dating techniques and from published accounts. Tree growth in four forests adjacent to the end moraine was measured by increment borings of 200 *Picea engelmannii*. Drawings of increment cores were made in the field, to avoid differential shrinkage with storage. From these drawings, tree growth was calculated in trunk basal area per decade.

Total tree growth was higher from 1581 to 1680, 1761 to 1790, 1851 to 1870, and 1901 to 1960 with lower growth intervening. Total growth was positively related to world temperature and sunspot activity and negatively related to world precipitation and glacial activity.

Records of glacial activity in Alberta, British Columbia, Washington, and Oregon from 1580 to 1960 showed that two intervals, 1711 to 1724 and 1835 to 1849, contained over one-half of the glacial advances. These intervals followed the two lowest periods of solar activity (1645-1715; 1798-1833) since 1610. Periods of high solar activity showed glacial retreat or stagnation. These results support the solar radiation climatic hypothesis.

Résumés of forest growth, glacial activity, climatic regime, and solar activity for 1580-1960 and 800-1950 gave further evidence of a close relation between solar activity and climate. The use of solar activity data in predicting climatic trends and glacial activity was discussed.

pA.A.

112. **BRERETON, W.E., and J.A. ELSON. 1979. A late Pleistocene plant-bearing deposit in Currie Township, near Matheson, Ontario. Canadian Journal of Earth Sciences 16(5):1130-1136.**

Two overburden test holes drilled to bedrock in Currie Township, southwest of Matheson, Ontario, penetrated stratified beds containing fossil plant detritus resting on an oxidized substrate, which are between two till sheets underlying glacial Lake Ojibway-Barlow varved clays. The fossil plants, chiefly mosses, represent an environment that is common in the region today, and are radiocarbon dated (GSC-2148) as older than 37,000 years. The interglacial deposit is tentatively correlated with the Missinaibi Formation in the Moose River basin of the James Bay lowlands, probably of Sangamon age.

A.A.

113. **BRIGHAM, J.K. 1979. Amino acid geochronology of Quaternary glaciomarine sediments, Broughton Island, S.E. Baffin Island, N.W.T., Canada. Geological Society of America, Abstracts with Programs 11(7):394.**

Marine and glaciomarine terraces on Broughton Island record evidence of glacio-isostatic adjustments and eustatic sea level changes. Because of the discontinuous nature of the deposits, both laterally and temporally, stratigraphic control is provided by amino acid ratios (D-allo-isoleucine/L-isoleucine in the free fraction) of marine molluscs collected from cliff exposures. D-allo/L-iso ratios subdivide the deposits into six units which suggest that local ice advanced around Broughton Island to the outer coast at least once during early-Foxe time (ca. 100,000? BP) and twice during mid-Foxe time (ca. 60-70,000? BP). Maximum marine transgressions during these advances reached 72 m, >35 m, and between 30 and 70 m, respectively. Biostratigraphic evidence indicates that subarctic water, warmer than present, occupied this region during glacial maxima. Late-Foxe time (ca. 25,000-8,500? BP) was characterized by only small local ice advances on the adjacent Baffin mainland and by eustatic sea level changes created by growth of the Laurentide ice sheet along its southern margin. An early Holocene (ca. 8,000 BP) sea level rise eroded a prominent bench in older sediments at 7-9 m a.s.l.

Correlative sequences of glacial and sea level events are recorded in raised terraces 50 km and 350 km north of Broughton Island, suggesting that glacial fluctuations were synchronous along the northeast coast of Baffin Island. The chronology of the region stands in marked contrast to that along the southern margin of the Laurentide ice sheet complex, emphasizing the asymmetrical shift of glacial advances from north to south through Foxe (Wisconsin?) time.

A.A.

114. BRINKMANN, W.A.R. 1976. Surface temperature trend for the Northern Hemisphere - updated. Quaternary Research 6(3):355-358.

The surface temperature curve for the Northern Hemisphere was extended to include the years 1969 through 1973 following the same procedure used by H.C. Willett, J.M. Mitchell, Jr., and C.H. Reitan. The analysis showed a slight warming of 0.02°C between the periods 1965-1969 and 1970-1973, and a significant decrease in the number of negative temperature changes at individual stations (indicating a decrease in the total area experiencing temperature decrease).

A.A.

115. BRINKMANN, W.A.R., and R.G. BARRY. 1972. Palaeoclimatological aspects of the synoptic climatology of Keewatin, Northwest Territories, Canada. Palaeogeography, Palaeoclimatology, Palaeoecology 11(2):77-91.

Mean monthly composite patterns of surface weather anomalies and 700 mbar height anomalies are determined for snowy winters and cool summers in both Keewatin and Labrador-Ungava and also for different positions of the mean 700 mbar trough over eastern Canada. The results indicate that for the selected regimes precipitation anomalies are characteristically of opposite sign in Keewatin and northern Ungava whereas temperature conditions in the two areas are comparable. The implications of the findings are discussed with reference to post-Glacial palynological evidence from Arctic Canada and to the possible conditions favouring inception of glaciation in Keewatin.

A.A.

116. BROOKES, I.A., J.H. McANDREWS, and P.H. VON BITTER. 1982. Quaternary interglacial and associated deposits in southwest Newfoundland. Canadian Journal of Earth Sciences 19(3):410-423.

A record of late Quaternary environmental change is preserved in sediments near Codroy, Newfoundland. This coastal cliff section exposes five units. Pollen and spores from unit 3 indicate that during its deposition regional vegetation changed from tundra (Zone A) to boreal forest (Zone B), and back to tundra (Zone C), through an interglacial cycle of vegetation change. Balsam fir wood from Zone B is radiocarbon-dated to >40,000 BP. Zone B is assigned full interglacial status, based on pollen and foraminiferal evidence, and is tentatively considered to represent the Sangamon interglacial.

C.R.H.

117. BROOKS, C.E.P. 1970. Climate Through the Ages. A Study of the Climatic Factors and their Variations. 2nd revised edition. Dover, New York. 395 pp.

"The book is divided into three sections. In the first, the various factors of climate are discussed, and the scope which they offer for the introduction of climatic changes is considered, quantitatively when possible. This part of the work is essentially a textbook of meteorology... Various theories of climatic change are discussed in successive chapters as they arise, but no attempt has been made to include all the theories which have been put forward from time to time."...

"The second section of the book applies the principles laid down in the first section to the various problems presented by geological climates." ... The third section of the book deals in considerable detail with the climates of different parts of the world during the historical period, or from about 5000 B.C. to the present day.

Chapters of particular relevance to this bibliography include Chapter 16 "The Climate of the Quaternary" and Chapter 21 "America and Greenland".

A.B.S.

118. **BROWN, J.-L., et P. Gangloff. 1980. Géliformes et sols cryiques dans le sud de l'Abitibi, Québec. Géographie physique et Quaternaire 34(2):137-158.**

Evidence of fossil as well as active patterned ground has been found in forested areas some 400 km south of the permafrost zone, in the southern part of Abitibi (Québec). This paper describes the occurrence of sorted and non-sorted patterned ground and stresses the paleoclimatic and pedologic importance of this feature.

pA.A.

119. **BRYSON, R.A., W.N. IRVING, and J.A. LARSEN. 1965. Radiocarbon and soil evidence of former forest in the southern Canadian tundra. Science 147(3653):46-48.**

Radiocarbon dating of charcoal on podzols along a transect reaching 280 kilometers north of the present tree line from Ennadai Lake indicates that former forests were burnt about 3500 years ago and again about 900 years ago. These forests probably were associated with periods of relatively mild climate.

The history that emerges from this stratigraphy is as follows. After the draining of great glacier-dammed lakes in southwestern Keewatin not later than 3500 B.C., forest encroached northward to at least about 63°N and remained until about 1500 B.C., developing a typical podzol soil. About 1500 B.C. the forest failed to regenerate after fires, and the tree line retreated south to Ennadai Lake. By A.D. 1000 the forest had again advanced to at least 61°30'N or 62°N. Fires of that time were not followed by forest regeneration north of the present tree line.

Thus, the tree line twice advanced north of its present position and was farther south than at present during an intervening period between 1500 B.C. and A.D. 1000. Because the tree line presently coincides with the position of the Arctic front, we infer that these periods of northward forest extension were periods with a more northerly frontal position. Judging that the advances represent periods of relatively milder climate, we correlate the first advance with the Climatic Optimum and the second with the Little Climatic Optimum.

The known history of human occupancy of this area also reflects this sequence of biotic and climatic change. Late Paleo-Indian (Protoarchaic) artifacts, like those of buffalo hunters in the Plains and Great Lakes regions 7000 to 9000 years ago, are found on sites exposed after the draining of the proglacial lakes in the Dubawnt and Kazan river systems. These sites were forested until 3500 years ago. The first arrival of Arctic culture in the region (pre-Dorset stage of the Arctic small-tool tradition) probably took place 3000 to 4000 years ago, with the onset of more severe climate and the retreat of the forest border. The recent Caribou Eskimo came after the forest retreat of 900 years ago.

A.A.$^{+}$

120. **BRYSON, R.A., and J.A. KUTZBACH. 1974. On the analysis of pollen-climate canonical transfer functions. Quaternary Research 4(2):162-174.**

Canonical correlation analysis ... provides a means of reconstructing past climates quantitatively from fossil pollen using a pollen-climate transfer function. This paper presents a method for analysis of variance of the transfer function model. This method is used to identify ecological relationships among the pollen and climate variables, to select climatically sensitive taxa, and to investigate the importance of site factors.

pA.A.

121. BRYSON, R.A., and T.J. MURRAY. 1977. Climates of Hunger: Mankind and the World's Changing Weather. University of Wisconsin Press, Madison. 171 pp.

This book provides a broad overview of climatic change, illustrating the importance of examining the past in order to prepare for the future. The effects of some past climatic changes on civilizations are presented and force an awareness of the implications of climatic variation.

A.B.S.

122. BRYSON, R.A., and W.M. WENDLAND. 1967. Tentative climatic patterns for some late glacial and post-glacial episodes in central North America. University of Wisconsin, Department of Meteorology Technical Report 34:1-27. (Also published in: Life, Land and Water. Edited by: W.J. Mayer-Oakes. University of Manitoba, Department of Anthropology Occasional Papers No. 1:271-298. 1967).

Reconstructs airmass regimes over North America (1) during the late glacial period ca 12,000 BP. (2) the period 9000-8000 BP. (3) 5000-3500 BP. Using the technique developed by the authors which delineates air mass boundaries and fronts by reference to boundaries of biotic communities, maps are presented for each period showing mean frontal positions and circulatory patterns. During the late glacial period the upper westerlies were strong along 40-45° in summer while winters were warmer than present over the U.S. The authors consider it inconceivable that the Arctic Ocean should have been ice-free or even partially open. Changes to Boreal conditions (period 2) were abrupt and the resulting climatic and vegetational patterns are described. At this time subsident Pacific air extended further east than at present, and grasslands were more extensive. Changes to early sub-Boreal time (period 3) and subsequently are outlined. A consistent matching of climatic pattern and biotic evidence can be demonstrated for the past 10,000 years. This is particularly true of the Boreal forest in the sub-Arctic.

A.B.

123. BRYSON, R.A., and W.M. WENDLAND. 1967. Carbon isochrones of the retreat of the Laurentide ice sheet. University of Wisconsin, Department of Meteorology Technical Report No. 35:1-26.

Presents a map showing the position of the ice front at 500 year intervals over the last 13,000 years. The retreat is shown to have averaged 12 mi/century over much of eastern North America. The computational method using radiocarbon dates is explained. Of the many dates used, isarithmic analysis showed that surprisingly few were clearly incorrect. The most striking conclusion is the continuous presence of the ice sheets until well after the accepted close of Wisconsin time ca. 10,500 BP, with continental ice sheets persisting through the entire hypsithermal period. Hudson Bay and Foxe Basin cleared early (ca. 8000 BP), and a broad low corridor opened from the Arctic to the Plains in Boreal time (ca. 8500 BP). The paleoclimatological implications of the study are discussed.

A.B.

124. BRYSON, R.A., W.M. WENDLAND, J.D. IVES, and J.T. ANDREWS. 1969. Radiocarbon isochrones on the disintegration of the Laurentide Ice Sheet. Arctic and Alpine Research 1(1):1-14.

The last great event of the Wisconsin Glacial Stage in North America was the disintegration of the Laurentide Ice Sheet. This occurred between 13,000 and about 5,000 years ago and had a profound effect upon the paleogeography of the continent. Analysis of present-day distribution of fauna and flora, the archaeological record, and climatic and sea-level fluctuations are intimately bound up with ice sheet disappearance, yet there has been no systematic attempt to utilize existing radiocarbon and geological data to attempt a plot of the ice sheet perimeter at specific intervals through time. The present paper makes this attempt in the form of two maps, the first being an objective portrayal of isolines drawn on the radiocarbon data, the only assumption being that the ice sheet perimeter tended to parallel the coastline or, more particularly, the trend of the outer edge of the continental shelves and the southern limit of Wisconsin till on land; the second map is a subjective interpretation of the first based up geologic field evidence and the climatic and geomorphic intuition of the writers. Some of the immediate implications raised by the maps are discussed and a series of significant conclusions are derived: (1) The northern limit of the Laurentide Ice Sheet proper was close to the arctic mainland coast of Canada. (2) There was a dramatic change from an east-west ice barrier near latitude 60°N in late-glacial time, to a broad low corridor from the Arctic Ocean to the Great Plains in Boreal time. (3) The Laurentide Ice Sheet retained its identity as a distinct unit until about 8,400 years BP (Cockburn Stade) and had catastrophically disintegrated during Atlantic time within a few centuries of 8,000 years BP. (4) The three remaining ice remnants centered over Keewatin, Labrador-Ungava, and Foxe Basin-Baffin Island persisted through the Atlantic climatic episode (altithermal), that on Baffin Island surviving to the present day in the form of the Barnes Ice Cap.

A.A.

125. **BUDD, W.F. 1981. The importance of ice sheets in long term changes of climate and sea level. In: Sea Level, Ice, and Climatic Change. Edited by: I. Allison. International Association of Hydrological Sciences Publication 131:441-471.**

A review of the effects of ice sheets on climate as indicated by modelling studies, reveals that the presence of the ice sheets themselves was the major factor causing the lower climatic temperatures prevailing during the ice ages. A review of other modelling studies of the climatic effects of the changing radiation regime, resulting from the Earth's orbital variations, indicates that the changes are large enough, and of sufficient duration, to cause the initiation and termination of the ice ages when the added feedback of the ice sheets on the climate is included. To understand the effect of the orbital radiation changes it is important to differentiate between annual, summer and June-July periods all as functions of latitude and whether over land or sea. In particular the June-July changes over land at high latitudes are very high whereas the global annual changes are negligible. These concepts and modelling results resolve a number of anomalies in previous palaeo climate studies. A review of palaeo evidence for changes of ice extent, sea level and climate provides considerable support for the results of model calculations of ice sheet and climate response to the orbital variations. These responses show three major periods of lower temperatures and greater ice extent over the last 120,000 years, separated by periods of milder climate with low land-ice volumes. In reconciling this pattern with sea-sediment isotope records it is important also to consider a strong isotope component from the Antarctic ice sheet.

A.A.

126. **BUDD, W.F., and I.N. SMITH. 1981. The growth and retreat of ice sheets in response to orbital radiation changes. In: Sea Level, Ice, and Climatic Change. Edited by: I. Allison. International Association of Hydrological Sciences Publication 131:369-409.**

Present day ablation rates are examined in terms of the present radiation and temperature regimes. The net accumulation ablation balance regime is derived as a function of position and elevation from present day precipitation and ablation rates. The net ablation rate as a function of elevation for each location is then considered to vary in time with the summer radiation regime resulting from the Earth's orbital changes as originally proposed by Milankovitch and more recently calculated by Vernekar. A three-dimensional time dependent ice sheet model based on an empirical flow relation derived from present measured ice sheet velocities is used to study the effects of the orbital radiation changes and resulting balance changes on the Northern Hemisphere ice sheets. The balance is dependent on location, time and elevation. The location and time variation is prescribed along with the form of the elevation dependence which is then calculated with time as a result of the current computed ice sheet elevations. The time period studied is from about 120,000 years BP up to the present. The present ice sheets and bedrock elevations have been digitized on different grids to study the differences between small-scale and large-scale reactions. Sensitivity studies have also been carried out to examine the conditions required for the growth of the Laurentide ice sheet and for its subsequent disappearance. Net ice-volume changes are tracked as a function of time and the subsequent effects on sea level are compared with independent evidence for past sea-level changes derived form geographical sources.

A.A.

127. BUDYKO, M.I. 1969. The effect of solar radiation variations on the climate of the earth. Tellus 21(5):611-619.

Many of the hypotheses about changes in climate failed because they were based mainly on qualitative considerations allowing different interpretations. To avoid this, Budyko suggests using quantitative methods based on physical climatology to study this problem of the explanation of changes in climate. It is found that over the last century there is a close similarity between the values of direct solar radiation with cloudless skies and secular temperature variations. To develop this theme, the influence of long-term changes of radiation, caused partly by variations of atmospheric transparency on the thermal regime of the earth is to be studied. Allowing for the effects of changes in planetary albedo due to glaciation, it is suggested that the present thermal regime of the earth is characterized by high instability and that comparatively small changes of radiation, perhaps only 1-2%, would be sufficient for the development of ice cover on land and oceans down to temperate latitudes. To account for the more stable climatic conditions of pre-Tertiary times, it is considered that the northern polar basin was connected with the oceans of low latitudes with much wider straits compared with the Quaternary. In this case, the heat income to the basin as a result of sea currents was more than enough to compensate for reductions in radiation to volcanic eruptions. During the Tertiary period, isolation of the polar basin increased and hence the effect of volcanic activity became more important.

G.A.

128. BUDYKO, M.I., and K.Ya. VINNIKOV. 1973. Modern climate variations. Meteorology and Hydrology 9:1-13.

The analysis of the secular courses of transparency of the atmosphere, the thermal regime, and the hydrologic cycle for the extraequatorial zone of the Northern Hemisphere shows that over the greater part of the last century the primary factor determining the variations in climatic conditions was the fluctuations of the aerosol concentration in the lower stratosphere and the variations in the total solar radiation connected with them. During the last two or three decades, the anthropogenic factors have begun to have a noticeable effect.

G.A.

129. BUTZER, K.W. 1976. Pleistocene climates. In: Ecology of the Pleistocene. Edited by: R.C. West and W.G. Haag. Geoscience and Man 13:27-44.

The entire data base for objective synoptic reconstructions in palaeoclimatology has been greatly enhanced during the past several decades. The descriptive model of mid-Tertiary climate differs conspicuously from that of the Holocene interglacial and Pleistocene glacials. Significant and repeated oscillations of climate already marked the Pliocene and assume ecological prominence during the early Pleistocene, with full-scale glacial-interglacial cycles established by 700,000 BP. The nature of these cycles is discussed, and it is proposed that the term glacial be restricted to times of continental glaciation on Europe and North America. The Last Interglacial and Last Glacial, so defined date from about 125,000 to 75,000 and about 75,000 to 11,000 BP, respectively. The temporal evolution and spatial patterning of these episodes are described and analyzed, and an explanatory model is presented for the climatic anomalies of the Last Glacial. Finally, the differing wavelengths of first-to sixth-order climatic changes are discussed briefly in terms of potential causative factors.

G.A.

130. CAILLEUX, A. 1973. Eolisations periglaciaires quaternaires au Canada. Biuletyn Peryglacjalny 22:81-115.

Certainly, the wind-action has been enhanced in the Prairies, since at least the Eocene and until now by the well-known continentality and relative aridity. But its renewed outbreak in the Quaternary requires other favouring factors: most probably, during the cold phases, the low temperature and frost, which thwarted the vegetal cover and left the ground freely exposed to the strong winds. This periglacial explanation is supported by the association, in the Quaternary of Edmonton, of high percentages of wind-worn grains, to unequivocal signs of cold climate, such as involutions, pseudomorphs of typical ice-wedges, sand wedges ... etc., testifying to mean annual temperatures of at least -2° to -6°C, against +2° to +4°C presently.

pA.A.

131. CALLENDAR, G.S. 1955. A close parallel between temperature fluctuations in East Canada and Britain. Royal Meteorological Society Quarterly Journal 81(347):98-99.

A surprising similarity of temperature fluctuation on both sides of the Atlantic is revealed by examining 10-year moving means of temperature at Kew with that of a group of five stations in Southern Ontario. The cause would seem to be a matter for meteorologists who study wave patterns in the zonal westerlies.

Thomas

132. CARDER, A.C. 1962. Climatic trends in the Beaverlodge area. Canadian Journal of Plant Science 42(4):698-706.

Analysis of the weather records at Beaverlodge from 1916 to 1960 revealed that, although mean annual temperature increased over this time only ½°F, the warming trend in the spring and fall was for some reason three times greater. This latter condition is very likely responsible for the marked lengthening of frost-free period over the 45 years. Annual precipitation increased almost 2 inches with wetter springs, summers and autumns, but there was a decrease in winter snowfall. The tendency for warm, cool, wet or dry years to come in groups was marked, but there was no association between the occurrence of these different types of years. The data were insufficient to determine if any recurrence was cyclic.

A.A.

133. CARRARA, P.E., and J.T. ANDREWS. 1972. The Quaternary history of northern Cumberland Peninsula, Baffin Island, N.W.T. Part I: The Late-and Neoglacial deposits of the Akudlermuit and Boas Glaciers. Canadian Journal of Earth Sciences 9(4):403-414.

Moraines of local glaciers predating the Neoglacial occur in sections of northern Cumberland Peninsula. A study of these deposits is reported for the area between the heads of Quajon and Narpaing Fiords. A chronology is developed based on lichenometry, percent of lichen cover, and the weathering of boulders and pebbles. Initial dating is done by lichenometry and dates older than about 6000 BP are attempted by establishing rates of weathering. About 12 500 BP glaciers existed in both south- and north-facing corries with an equilibrium line at 850 m a.s.l. During the next 5000 years the south-facing glaciers retreated and disappeared. About 7000 BP, moraines were deposited in front of the Akuldermuit and Boas glaciers[1] - these moraines are no longer ice-cored. The equilibrium line lay between 850 and 975 m.a.s.l. A 'warm' interval followed and the ice-cores melted. This was followed by an early Neoglacial advance, dated about 3800 BP for the period of moraine stabilization; after a 2000 year interval four younger readvances are recorded. All Neoglacial moraines are ice-cored. During the last few decades the equilibrium line has risen.

A.A.

134. CATCHPOLE, A.J.W. 1980. Historical evidence of climatic change in western and northern Canada. In: Climatic Change in Canada. Edited by: C.R. Harington. Syllogeus 26:17-60.

The author first provides an introduction to the nature and role of historical evidence of climatic change. Types and sources of this evidence in western and northern Canada are given; these include Hudson's Bay Company records, Royal Canadian Mounted Police records, Dominion Land Surveyors' records, Church and Missionary records, and private records. Relevant climatic information identified from each of these sources and its validity and usefulness in reconstructing the past is discussed.

A.B.S.

135. CATCHPOLE, A.J.W., and T.F. BALL. 1981. Analysis of historical evidence of climatic change in western and northern Canada. In: Climatic Change in Canada 2. Edited by: C.R. Harington. Syllogeus 33:48-96.

Analyses of historical climatic evidence, now in progress at the Universities of Manitoba and Winnipeg, are based entirely upon Hudson's Bay Company records. The objective is to thoroughly explore the utility of this valuable historical climatic resource before other potential Canadian historical sources are examined (Catchpole, 1980). This report deals with three major aspects of this research: (1) a study of ice conditions on northern rivers and seas; (2) a reconstruction of dates of first snowfall and first frost in the Hudson Bay region; (3) the development of a computer-coding system for the retrieval and analysis of climatic information in the Hudson's Bay Company post journals. The immediate goal of this report is to present results which have been obtained to date and to outline the methods of analysis being applied. Interpretation of these and subsequent findings in the light of knowledge of climatic change in the historical period will be presented in a later report.

Records were obtained from Churchill Factory (1718-1866), York Factory (1714-1850), Moose Factory (1736-1870), Fort Albany (1721-1921), Eastmain House (1743-1837, 1893-1921), and Severn House (1761-1897).

A.I.+

136. CATCHPOLE, A.J.W., D.W. MOODIE, and B. KAYE. 1970. Content analysis: a method for the identification of dates of first-freezing and first-breaking from descriptive accounts. The Professional Geographer 22(5):252-257.

"This paper endeavors to contribute to the study of freeze-up and break-up dates by establishing a procedure for extracting quantitative data from historical accounts. Methods of content analysis are applied to the journals of three Hudson's Bay Company fur trading posts in the interior of western Canada. The posts, selected on the criteria of length and continuity of the journal records, were located as follows: Edmonton House on and near the site of present Edmonton, Alberta; Cumberland House on the south shore of Cumberland Lake, Saskatchewan; Norway House on the southeast shore of Little Playgreen Lake, Manitoba." The authors review the inaccuracies in the results; observational subjectivity is the primary difficulty to overcome.

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[1] Ed note: These glacier names have not been accepted by the Canadian Permanent Committee on Geographic Names.

A.B.S.

137. CATCHPOLE, A.J.W., D.W. MOODIE, and D. MILTON. 1976. Freeze-up and break-up of estuaries on Hudson Bay in the eighteenth and nineteenth centuries. Canadian Geographer 20(3):279-297.

This paper analyses changes in dates of freeze-up and break-up at four river estuaries on Hudson Bay in the period 1714-1871. The dates have been reconstructed from daily journals kept by personnel of the Hudson's Bay Company and concern the estuaries of the Moose, Albany, Hayes, and Churchill rivers. The journals are those kept at Moose Factory, Fort Albany, York Factory, Churchill Factory, and Fort Prince of Wales. The locations of the keeping of the journals in both time and space are shown in Figure 1. The first part of the paper is concerned with the origin and nature of these dates as measures of change in the freezing and breaking processes. The second part describes the changes they exhibit.

A.A.

138. CATTO, N.R., R.J. PATTERSON, and W.A. GORMAN. 1981. Late Quaternary marine sediments at Chalk River, Ontario. Canadian Journal of Earth Sciences 18(8):1261-1267.

The occurrence of marine clays and silts in the Chalk River area necessitates a revision of the previously accepted position of the northwestern extent of the Champlain Sea in the Ottawa Valley. The marine origin of these deposits is demonstrated by sedimentological, geochemical, and paleontological criteria. Boron and Vanadium concentrations indicate a salinity for this part of the Champlain Sea of from 12 to 16 parts per thousand. Foraminifera present in the clays suggest a shallow brackish water environment. An evaluation of elevations of the marine limit indicates that the sea was present at Chalk River between about 11 300 and 11 100 years BP and thus was a relatively late phase of the Champlain Sea. It appears that ice cover in the area had prevented an earlier inundation by Champlain Sea waters.

Till overlying the marine sediments is attributed to a minor readvance starting about 11 000 years ago. The timing and geographic location of this advance strongly indicate a correlation with the St. Narcisse event, well documented to the east of the Ottawa Valley. With the subsequent ice retreat, aeolian and lacustrine and, later, fluvial conditions prevailed, as isostatic recovery had elevated the area above the existing sea level.

A.A.

139. CATTO, N.R., R.J. PATTERSON, and W.A. GORMAN. 1982. The late Quaternary geology of the Chalk River Region, Ontario and Quebec. Canadian Journal of Earth Sciences 19(6):1218-1231.

Glacial ice covered the Chalk River area through most of the Wisconsin Stage. About 11 300 years ago, an ice retreat was followed immediately by a short incursion of Champlain Sea waters, which deposited at least 2.5 m of clay, silt, and sand. A local readvance, probably associated with the St. Narcisse event, deposited till on the marine sediments. Following the final retreat of the ice from the area, lacustrine and aeolian deposition occurred locally for a short time.

About 10 500 years ago, the North Bay drainage route opened, greatly increasing the discharge of the Ottawa River. A faint terrace at a present elevation of 209 m probably formed at this time. Changes in the drainage routes of proglacial lakes and in the rate of ice retreat caused a general decrease in discharge rates, and resulted in the formation of pronounced terraces, now at 180, 160, and 129 m, and fainter terraces at 170, 141 and 137 m. By about

5000 years BP, the North Bay outlet closed, and the river fell to approximately 111 m, its present elevation at Chalk River.

During the whole period of terrace formation, alluvial sands were being deposited and, as river levels fell, exposed sands were reworked by the wind until anchored by vegetation. Charcoal horizons within the aeolian sequences indicate that forest fires occasionally destroyed the vegetation cover, re-initiating aeolian activity. Locally, active dunes are present near Chalk River, but most of the area has been stabilized by vegetation.

A.A.

140. Causes of Climatic Change. Proceedings of the VII INQUA Congress, Volume 5. Edited by: J.M. Mitchell. Meteorological Monographs 8(30):1-159. 1968.

A collection of papers derived from the INQUA-NCAR Symposium on causes of climatic change. Relevant papers have been abstracted separately.

A.B.S.

141. CERMAK, V. 1971. Underground temperature and inferred climatic temperature of the past millennium. Palaeogeography, Palaeoclimatology, Palaeoecology 10(1):1-19.

There is considerable evidence from different fields of investigation that the world climate has undergone significant variations, even during the last 1,000 years. The effect of the change of temperature on the earth's surface in the past may be preserved at depths of several hundred feet below the surface. The relation between underground and surface temperature is the reaction of the internal field in a semi-infinite medium to the boundary conditions. Any change at the surface is propagated downwards, and it is shown that the detailed record of temperature with depth can be used to trace the past climatic history. The theory of climatic correction of heat flow are used, and the data are obtained from two boreholes in northeastern Ontario. After analysis the underground temperature clearly confirmed the notably warm climate that lasted a few hundred years around A.D. 1000-1200 and the following cold period after 1500. Both these recent climatic extremes, for which the terms "Little Climatic Optimum" and "Little Ice Age" were coined, are well substantiated, but the magnitude of the temperature variations is uncertain. The relation between mean annual air temperature and surface (ground) temperature depends very much on the precipitation character and the duration of snow cover. The calculated magnitudes of the surface temperature changes probably correspond to the minimum changes of the annual air temperatures, which might have been more pronounced. The data presented indicate for the Kapuskasing area a surface temperature during the Little Climatic Optimum at least 1.5°C higher than the reference value; the mean temperature during the Little Ice Age was about 1°C below this reference value. A remarkable increase since about 1850 has a value in excess of 3°C.

A.A.

142. CHAKRAVARTI, A.K. 1976. Precipitation deficiency patterns in the Canadian Prairies, 1921-1970. Prairie Forum 1:95-110.

Serious precipitation deficiencies causing droughts vary widely both in areal extent and in time throughout the agricultural area of the Prairie Provinces. Since there is no universally agreed definition of droughts, and since the availability of water for farming in the Prairies largely depends on precipitation, precipitation deficiencies according to decile ranges have been mapped to relate such deficiency patterns with the drought-affected areas as reported by various government agencies and newspapers. The lowest first and second decile ranges of annual precipitation indicate a general relationship with severe to moderate drought conditions as reported for different parts of the Prairies between 1921 and 1970. Further, it was noticed that even during the years of most deficient precipitation, as in the thirties, the agricultural areas of the three Prairie Provinces were not all affected equally. The percentages of agricultural area in the Prairies within the lowest two decile ranges of precipitation for each year from 1921 to 1970 have also been summarized for the three Prairie Provinces separately.

A general trend revealed here, and which needs further investigation based on detailed data from the northern prairies, is that, when the southern agricultural areas recorded precipitation much below normal, the northern areas received generally average to much above-average precipitation; the reverse was also true. This trend generally reflects the synoptic patterns involving an abnormal displacement of the North Pacific High Pressure cell, the jet streams and the cyclonic tracks. The lack of surface and upper-level weather data is a handicap to a more detailed and specifically a mesoscale synoptic analysis of precipitation-deficiency patterns, and consequently to a better understanding of the recurrence of unpredictable droughts in the Canadian prairies.

A.A.+

143. CHIU, Y.T. 1974. Archaeomagnetism and archaeoclimatic "forecast"? Nature 250(5468):642-643.

It has been suggested that the semipermanent pattern of depressions of tropospheric pressure in the north polar regions may be associated with areas of high magnetic field intensity in Canada and Siberia. I here test some aspects of the hypothesis by correlating archaeomagnetic and archaeoclimatic observations from various regions of the globe. Although there may be a tenuous correlation between them in some cases, the total pattern of archaeoclimatic regimes from central Europe to western America does not seem to follow the westward drift of the geomagnetic field pattern. I suggest that climatic regimes may be composed of a global component related to variations of the solar constant - and of a possible westward drifting component. The archaeomagnetic and archaeoclimatic evidence available at present indicates only a tenous correlation, at best.

G.A.

144. CHRISTIANSEN, E.A. 1979. The Wisconsinan deglaciation of southern Saskatchewan and adjacent areas. Canadian Journal of Earth Sciences 16(4):913-938.

The Wisconsinan deglaciation of southern Saskatchewan and adjacent areas of Alberta, Manitoba, Montana, and North Dakota is depicted in nine phases of glacial advance, readvance, and retreat. Although there is some uncertainty whether Phase 1 or 2 represents the Classical Wisconsin (Woodfordian) terminus, the glacial history from about 17000-10000 years ago is considered.

Although the glacier margin retreated at an increasing rate in Saskatchewan, the volume of meltwater released by the melting glacier decreased with time. The large meltwater channels south of the Cypress Hills as compared to those to the north, and the fact that most of the glacial lake deposits north of the Cypress Hills came from extraglacial rivers, suggest there was much more glacial meltwater activity south of the Cypress Hills than north of them. This in turn suggests that much of the ice melted before significant retreat of the ice front took place.

A.A.

145. CHURCHER, C.S., and R.L. PETERSON. 1982. Chronologic and evironmental implications of a new genus of fossil deer from Late Wisconsin deposits at Toronto, Canada. Quaternary Research 18(2):184-195.

A new cervine deer (*Torontoceros hypogaeus*) ... has been recovered from deposits of early Lake Ontario age on the exposed bench of Glacial Lake Iroquois at Toronto, Ontario, Canada. ... A ^{14}C date of 11,315 ± 325 yr BP obtained on the antler allows the date at which Glacial Lake Iroquois drained to be revised to before 11,400 yr BP. Spruce

(*Picea*), pine (*Pinus*), and sedges (Cyperaceae) are major components of the associated pollen spectrum, which implies a typically interstadial or postglacial climate in which mixed forests grew in the Toronto area.

pA.A.

146. CINQ-MARS, J. 1979. Bluefish Cave I: A late Pleistocene eastern Beringian cave deposit in the northern Yukon. Canadian Journal of Archaeology 3:1-32.

This paper is presented as an assessment report on the archaeological and paleoecological potential of a series of small cave and rock-shelter deposits located along the upper-middle course of the Bluefish River, northern Yukon Territory. It is based on the results of a preliminary investigation carried out during the 1978 Northern Yukon Research Programme field-season and deals primarily with data obtained from Bluefish Cave I, the largest of these features.

Our work at Bluefish Cave I has obviously resulted in accumulation of directly useable or potential information that goes well beyond the limits of our initial goals. We have at hand a late Pleistocene deposit, of a kind never encountered before in the northern Yukon, and containing traces of cultural activities which on the basis of a broad range of paleoenvironmental information can be tentatively dated from around 13,000 years ago to around 10,000 years ago. If the cultural evidence belonging to the later part of the sequence may be tentatively assigned to a Diuktai continuum, the earlier one remains anonymous and can only be taken as indicative of a human presence in the Porcupine River basin after the end of the last glacial maximum. This greatly reduces the length of an apparent regional cultural hiatus and can be taken as suggestive that human populations were technologically capable of coping with near-glacial environmental conditions that ceased to exist around or shortly after that time. It also implies that these or other eastern Beringian groups could very well have been present sometime earlier, during the coldest phases of the glacial maximum, and it leaves ample room for future speculative exercises concerning the relationships that may have existed between those populations and those that were to manifest themselves around 12,000 years ago to the south of the continental ice sheet, as well as with the much earlier Beringian interstadial populations.

Excerpts

147. CLAGUE, J.J. 1976. Quadra Sand and its relation to the late Wisconsin glaciation of southwest British Columbia. Canadian Journal of Earth Sciences 13(6):803-815.

Quadra Sand is a late Pleistocene lithostratigraphic unit with widespread distribution in the Georgia Depression, British Columbia and Puget Lowland, Washington. The unit consists mainly of horizontally and cross-stratified, well sorted sand. It is overlain by till deposited during the Fraser Glaciation and is underlain by fluvial and marine sediments deposited during the preceding nonglacial interval.

Quadra Sand was deposited progressively down the axis of the Georgia-Puget Lowland from source areas in the Coast Mountains to the north and northeast. The unit is markedly diachronous; it is older than 29000 radiocarbon years at the north end of the Strait of Georgia, but is younger than 15000 years at the south end of Puget Sound.

Aggradation of the unit occurred during the climatic deterioration at the beginning of the Fraser Glaciation. Thick, well sorted sand was deposited in part as distal outwash aprons at successive positions in front of, and perhaps along the margins of, glaciers advancing from the Coast Mountains into the Georgia-Puget Lowland during late Wisconsin time.

The sand thus provides a minimum age for the initial climatic change accompanying the Fraser Glaciation. This change apparently occurred before 28800 years BP, substantially earlier than glacial occupation of the southern Interior Plateau of British Columbia. Thus, several thousand years may have intervened between the alpine and ice-sheet phases of the Fraser Glaciation.

A.A.

148. CLAGUE, J.J. 1977. Quadra Sand: a study of the late Pleistocene geology and geomorphic history of coastal southwest British Columbia. Geological Survey of Canada Paper 77-17:1-24.

Quadra Sand is a late Pleistocene lithostratigraphic unit with widespread distribution in the Georgia Depression, British Columbia and Puget Lowland, Washington. The unit consists of horizontally and cross-stratified, well-sorted sand, minor silt, and gravel. It is overlain by till and related glacial sediments deposited during the Fraser Glaciation and is underlain by fluvial, estuarine, and marine sediments deposited during the preceding nonglacial interval.

The unit is part of an apparently unbroken stratigraphic succession which records the major climatic oscillations of late Pleistocene time: till deposited during a pre-Fraser glaciation; glaciomarine sediments laid down during the subsequent transition to nonglacial conditions; marine, estuarine, and fluvial sediments deposited during the Olympia nonglacial interval; outwash deposited during the following nonglacial-glacial transition; and till deposited under full glacial conditions of the Fraser Glaciation.

Stratigraphic evidence, paleocurrent data, sand mineralogy, and radiocarbon dates indicate that Quadra Sand was deposited progressively down the axis of the Georgia Depression and Puget Lowland from source areas in the Coast Mountains to the north and northeast. The unit is markedly diachronous; it is older than 29,000 radiocarbon years at the north end of the Strait of Georgia but is younger than 15,000 years at the south end of Puget Sound.

Aggradation of Quadra Sand is thought to have been climatically induced. The initial influx of sand into the Georgia Depression probably occurred during a period of climatic deterioration at the onset of the Fraser Glaciation. The sand was deposited, in part, as distal outwash aprons at successive positions in front of, and perhaps along the margins of, glaciers moving from the coast Mountains into the Georgia Depression and Puget Lowland during late Wisconsin time. After deposition at a site, but before burial by ice, the sand was dissected by meltwater and the eroded detritus was transported farther down the basin to sites where aggradation continued.

Quadra Sand buried older fluvial and estuarine deposits which, in turn, were laid down over marine sediments filling much of the Strait of Georgia. The present patchy distribution of Quadra and older sediments is due, in large part, to scour by glaciers at the height of the Fraser Glaciation.

A.A.

149. CLAGUE, J.J. 1978. Mid-Wisconsinan climates of the Pacific Northwest. Geological Survey of Canada Paper 78-1B:95-100.

A controversy among earth scientists as to whether or not British Columbia and northwestern Washington were glaciated during mid-Wisconsinan time highlights the present uncertainty over late Pleistocene climates and environments in the Pacific Northwest. A review of relevant terrestrial lithostratigraphic and biostratigraphic information and selected paleoclimatic data from deep-sea cores shows that a lengthy nonglacial interval characterized by a sharply fluctuating, but generally cooler, climate occurred in the Pacific Northwest during mid-Wisconsinan time. Although remnant ice caps probably persisted in eastern and northeastern Canada during this interval, lowland areas adjacent to the presently glacerized mountains of western Canada were continuously ice free.

The Pleistocene Cordilleran glacier complex was controlled by different climatic factors from the Laurentide Ice Sheet. The precipitation and temperature regimes in the Cordillera, unlike those in other areas of Canada, are affected strongly by the Pacific Ocean. Both warm surface waters in the northeastern Pacific Ocean and reduced air temperatures probably were required for the growth of ice sheets in British Columbia, and these conditions apparently were not fulfilled during mid-Wisconsinan time.

A.A.

150. CLAGUE, J.J. 1980. Late Quaternary geology and geochronology of British Columbia; Part 1, Radiocarbon dates. Geological Survey of Canada Paper 80-13:1-28.

The "Radiocarbon Geochronology of Southern British Columbia" (Fulton, 1971) provides a summary of the radiocarbon dated Quaternary history of southern British Columbia and a compilation of most radiocarbon dates of geologic significance published before 1971. Since the publication of this important paper, new information has been gathered on the Quaternary of British Columbia. A much larger number of radiocarbon determinations is now available, resulting in a corresponding improvement in the chronology of geologic events of late to Quaternary age. The present report has been prepared to make available to researchers this expanded body of knowledge.

In the following tables, geologically relevant radiocarbon dates published prior to 1980 are presented within a late Quaternary geologic climate framework consisting of three parts: Olympia nonglacial interval (or interglaciation), Fraser for British Columbia and adjacent areas are compatible with this framework.

The radiocarbon dates are listed in eight tables as follows: Table 1, dates beyond the radiocarbon dating range; Table 2, finite dates on sediments of the Olympia nonglacial interval; Tables 3 and 4, dates pertaining to the advance and recessional phases of the Fraser Glaciation, respectively; Table 5, dates bearing on postglacial sea levels; Table 6, dates relating to volcanic flows and tephras; Table 7, dates bearing on postglacial climates; and Table 8, miscellaneous dates. The miscellaneous dates relate to (1) floodplain aggradation and degradation and deltaic progradation, (2) eolian activity, (3) landslides, (4) microfossil zonation in lakes and bogs, (5) prehistoric animal habitation, and (6) the relationship between radiocarbon age and sidereal age. Also in Table 8 are unclassified dates, including many from contaminated samples.

pA.I.

151. CLAGUE, J.J. 1981. Late Quaternary geology and geochronology of British Columbia. Part 2: Summary and discussion of radiocarbon-dated Quaternary history. Geological Survey of Canada Paper 80-35:1-41.

The Olympia nonglacial interval probably began more than 59,000 years ago. At times during this interval, temperatures were probably similar to, or cooler than, those at present. Apparently alpine glaciers did not spread into plateau or lowland areas of southern and central British Columbia. Climatic deterioration marking the Olympia nonglacial-Fraser Glaciation transition occurred during several thousand years. Fossil pollen studies in southwestern British Columbia indicate that between 29,000 and 21,000 years ago there was a gradual deterioration in climate marked by progressive replacement in lowland areas of temperate plants by subalpine, and finally alpine or tundra vegetation. The Cordilleran glacier complex reached its maximum extent about 15,000 years ago. Then climate warmed rapidly - perhaps mean July temperatures were 2 to 5°C lower than present on the Olympic Peninsula. Climate was probably as warm or warmer than present from 10,500 to 8,000 years ago until at least 6,600 years ago or later. This warm interval was followed in most regions by a cooler, moister period which has persisted until today. These data are mainly derived from paleobotanical and geological studies.

C.R.H.

152. **CLAGUE, J.J., J.E. ARMSTRONG, and W.H. MATHEWS. 1980. Advance of the late Wisconsin Cordilleran Ice Sheet in southern British Columbia since 22,000 yr BP. Quaternary Research 13(3):322-326.**

Radiocarbon dates from critical stratigraphic localities in southern British Columbia indicate that the growth history of the late Wisconsin Cordilleran Ice Sheet was different from that of most of the Laurentide Ice Sheet to the east. Much of southern British Columbia remained free of ice until after about 19,000 to 20,000 years ago; only adjacent to the Coast Mountains is there a record of lowland glacier tongues in the interval 22,000 to 20,000 yr BP. A major advance to the climax of late Wisconsin Cordilleran glacier ice in the northern States was not begun until after about 18,000 yr BP in the southwest of British Columbia and after about 17,500 yr BP in the southeast. The rate of glacier growth must have been very rapid in the two to three millennia prior to the climax, which has been dated in western Washington at shortly after 15,000 yr BP.

A.A.

153. **CLAGUE, J.J., R.H. GARDNER, K.E. RICKER, and M.W. DONLEY. 1977. Bibliography of marine geoscience information, Pacific regions of Canada, 1900-1976. Geological Survey of Canada Paper 77-22:1-43.**

A selective bibliography of marine geoscience information for Pacific regions of Canada has been compiled. Approximately 900 citations are indexed according to subject matter and geographic coverage.

The inventory area is bounded by Dixon Entrance on the north; the Gulf-San Juan Islands, Juan de Fuca Strait, and the continental margin southwest of Vancouver Island on the south; and by the inlets of mainland British Columbia and the Fraser Delta on the east. Included in this area is the continental margin west of the Queen Charlotte Islands and Vancouver Island, and that portion of the East Pacific Rise west of the continental slope. A large number of the more important studies of abyssal regions of the eastern North Pacific Ocean also are included.

An attempt to quantify perceptions of global climate change to the year 2000 has been the initial focus of an interdepartmental study at The National Defense University. Subjective probabilities for the occurrence of specified climatic events were elicited by a survey of 24 climatologists from seven countries. Individual quantitative reponses to ten major questions were weighted according to expertise and then averaged, a method of aggregation which preserved the climatologists' collective uncertainty about future climate trends. The aggregated The bibliography comprises published papers, maps, and readily available manuscript reports concerned wholly or partly with marine geology, geochemistry, and geophysics. Studies of Quaternary sediments and the crust beneath the seafloor constitute the bulk of the catalogued information, but maps and papers concerned with seafloor morphology, Quaternary sea level fluctuations, and processes of marine sedimentation and coastal erosion are included. Company reports, abstracts of papers presented orally at scientific meetings, and documents not accessible to the public have been excluded from this bibliography.

pA.A.

154. **CLAGUE, J., J.R. HARPER, R.J. HEBDA, and D.E. HOWES. 1982. Late Quaternary sea levels and crustal movements, coastal British Columbia. Canadian Journal of Earth Sciences 19(3):597-618.**

Late Quaternary sea-level fluctuations on the British Columbia coast have been established from studies of terrestrial and marine sediments and landforms. These studies indicate that the sea-level history of mainland British Columbia and eastern Vancouver Island is very different from that of the Queen Charlotte Islands and western Vancouver Island. Specifically, in the former areas, there was a rapid rise of submerged coastal lowlands between about 13 000 and 10 000 years ago. Emergence culminated about 6000-9000 years ago, depending on the locality, when the sea, relative to the land, was 12 m or more lower than at present in some areas. During middle and late Holocene time, relative sea level rose on the mainland coast and at least locally on eastern Vancouver Island, resulting in inundation of coastal archaeological sites and low-lying terrestrial vegetation. Tidal records and precise levelling suggest ongoing submergence of at least part of this region.

In contrast, shorelines on the Queen Charlotte Islands were below present from before 13 700 years ago until approximately 9500-10 000 years ago. A transgression at the close of the Pleistocene climaxed about 7500-8500 years ago when relative sea level probably was about 15 m above present in most areas. Most of the emergence that followed apparently occurred in the last 5000-6000 years. There has been a similar pattern of emergence on the west coast of Vancouver Island during the late Holocene time.

The above patterns of late Quaternary sea-level change are attributed to complex isostatic response to downwasting and retreat of the late Wisconsin Cordilleran Ice Sheet, to transfers of water from melting ice sheets to oceans, and to plate interactions on the British Columbia continental margin. Late Pleistocene and early Holocene crustal movements were dominantly isostatic. Although the recent regression on the outer coast likely is due, at least in part, to tectonic uplift, some late Holocene sea-level change in this area and elsewhere on the British Columbia coast may be either eustatic in nature or a residual isostatic response to deglaciation, which occurred thousands of years earlier.

A.A.

155. CLARK, D.L. 1969. Paleoecology and sedimentation in part of the Arctic Basin. In: U.S. Naval Arctic Research Laboratory Dedication Symposium, Fairbanks, Alaska, Proceedings. Arctic 22(3):233-245.

The author reviews the history of sedimentologic and resulting paleoecologic interpretations of the Arctic Basin. This is followed by a discussion of the more than 300 sediment cores obtained during the drift of T-3; analysis procedures, the factors studied, and possible implications of the results are presented. Investigations that appear promising for the future are briefly outlined.

A.B.S.

156. CLARK, D.L. 1982. Origin, nature and world climate effect of Arctic Ocean ice-cover. Nature 300:321-324.

During the Cenozoic, an open water Arctic Ocean changed to the modern permanently ice-covered condition. Significant global climatic effects accompanied this change. The author reviews three "theories" proposed to explain the evolution of the modern Arctic Ocean: (1) the "fluctuating regime" theory proposes that the late Miocene-Holocene interval was represented by three paleoclimatic regimes, only the most recent of which (occurring from approximately 0.7 M years to Recent) was characterized by a perennial ice-cover; (2) the "steady-state" theory, also based on interpretation of sediment cores, argues that the same kind of glacial-marine sediment that accumulates today under an average of 3 m ice, has been accumulating for at least 5 M years; (3) the "ice-cap" theory suggesting that Pleistocene sea level changes and oxygen isotope records from benthic foraminifera of the lower latitude oceans could be more easily explained if the Arctic Ocean had an Antarctic size ice-cap 1,000 m thick during all or most of the Pleistocene.

The author concludes that: glacial-marine sediment was forming in the central Arctic at least 5 M years ago; from then to the present, glacial-marine sediment, transported by icebergs and pack-ice, has accumulated in the central Arctic Ocean, and that these intervals of relatively rapid sedimentation attenuated with times of accumulation of finer-grained, mainly ice-pack transported sediment and greater organic productivity; from about 2 to 0.7 M years, calcareous dinoflagellates left a record of attenuating abundances and rareness - probably during this period surface conditions permitted greater productivity than had been possible before 2 or since 0.7 M years; there is no Arctic Ocean evidence to support the idea of ice caps 1,000 m thick during the Pleistocene; significant climatic changes are indicated if winter ice-cover is reduced and summer ice cover disappears from the Arctic Ocean as some climate modellers, postulating increased CO_2 in the atmosphere in future, predict.

C.R.H.

157. CLARKE, A.H. Jr., and J.S. ERSKINE. 1961. Pre-columbian *Littorina littorea* in Nova Scotia. Science 134(3476):393-394.

Littorina littorea, an abundant northeast North American gastropod, was thought to have been introduced from Europe about 1840. Shells of that species found on ancient Micmac Indian camp sites in Nova Scotia have been radiocarbon-dated as pre-Columbian. Failure of *L. littorea* to extend its range southward before 1840 may have been due to oceanographic factors.

A.A.

158. CLARKE, A.H., D.R. GRANT, and E. MACPHERSON. 1972. The relationship of *Atractodon stonei* (Pilsbry) (Mollusca, Buccinidae) to the Pleistocene stratigraphy and paleoecology of southwestern Nova Scotia. Canadian Journal of Earth Sciences 9:1030-1038.

The extinct Pleistocene buccinid gastropod *Atractodon stonei* (Pilsbry 1893), formerly known as *Neptunea stonei* (Pilsbry), has been found in a southern Nova Scotian deposit. The species had been previously reported only from (presumably) Sangamon deposits at Nantucket Island, Massachusetts and at other locations south to Cape Hatteras, North Carolina. Associated molluscs from all *A. stonei* deposits show that it probably lived in about 5 to 20 fm and in a climate like that of the present Acadian marine zoogeographic region.

Although the Nova Scotian specimens produced radiocarbon ages of 38,000 years BP, stratigraphic and paleoclimatological data indicate Sangamon age, and the radiocarbon dates are presumed to be too young. *Atractodon stonei* may qualify as a useful Pleistocene (Sangamon) index fossil representative of relatively specific paleoecological conditions.

A.A.

159. Climate Change Seminar Proceedings. Regina, March 17-19. Canadian Climate Centre, Downsview. 170 pp. 1981.

The Canadian Council of Resource and Environment Ministers sponsored a Climate Change Seminar in Regina, Saskatchewan, March 17-19, 1981. "This CCREM Seminar marks a milestone in the continuing dialogue among the governments in Canada concerning the sharing of knowledge and improving our understanding of climate and of the impacts of climate". This volume contains the provincial/territorial, federal and invited presentations together with group discussion reports. The presentations have been annotated individually by author.

A.B.S.

160. Climate Change to the Year 2000. A survey of expert opinion. Conducted by the Research Directorate of the National Defense University, Washington, D.C. 109 pp. 1978.

An attempt to quantify perceptions of global climate change to the year 2000 has been the initial focus of an interdepartmental study at The National Defense University. Subjective probabilities for the occurrence of specified climatic events were elicited by a survey of 24 climatologists from seven countries. Individual quantitative responses to ten major questions were weighted according to expertise and then averaged, a method of aggregation which preserved the climatologists' collective uncertainty about future climate trends. The aggregated subjective probabilities were used to construct five possible climate scenarios for the year 2000, each having a "probability" of occurrence. The aggregated probabilities of contingent events are compared from scenario to scenario, across zones of latitude, and by time periods.

The derived climate scenarios manifest a broad range of perceptions about possible temperature trends to the end of this century, but suggest as most likely a climate resembling the average for the past 30 years. Collectively, the respondents tended to anticipate a slight global warming rather than a cooling. More specifically, their assessments pointed toward only one chance in five that changes in average global temperatures will fall outside the range of -0.3°C to +0.6°C, although any temperature change was generally perceived as being amplified in the higher latitudes of both hemispheres. The respondents also gave fairly strong credence to a 20- to 22-year cycle of drought in the High Plains of the United States but did not agree on its causes.

Consequences of the possible climatic changes delineated in the scenarios are being considered in subsequent phases of this research. A generalized climate response methodology will be demonstrated by its application to crop yield data gathered from a survey of agricultural scientists. The policy implications of the resultant climate/crop scenarios will be examined using a world food economic model.

A.A.

161. Climatic Change. Edited by: J. Gribbin. Cambridge University Press, Cambridge. 280 pp. 1978.

This book intends to present "an overview of the basics of climatic change, intended for any scientifically literate person with an interest in climate". The various authors are specialists in different climate-related disciplines. Their contributions review current thinking on the subject of climatic change and provide the necessary background information for its comprehension. This volume takes a global approach to its subject.

A.B.S.

162. Climatic Change in Canada. Edited by: C.R. Harington. Syllogeus 26:1-246. 1980.

Five articles deal with the subject of climatic change in Canada during the past 20,000 years; a project of the National Museum of Natural Sciences. Articles are annotated individually.

A.B.S.

163. Climatic Change in Canada 2. Edited by: C.R. Harington. Syllogeus 33:1-220. 1981.

Eight articles provide results and interpretations of studies of climatic change in Canada during the past 20,000 years; National Museum of Natural Sciences Climatic Change Project. Articles are annotated individually.

A.B.S.

164. Climatic Changes in Arctic Areas During the Last Ten-Thousand Years. Edited by: Y. Vasari, H. Hyvärinen and S. Hicks. Acta Universitatis Ouluensis Series A, Scientiae Rerum Naturalium 3, Geologica 1:1-511. 1972.

Proceedings of a symposium held at Oulanka and Kevo, Finland, from October 4-10, 1971. "The Symposium hoped to achieve some coordination of current data from the Arctic by inviting to discussions active scientists from the various disciplines involved and by publishing their reports and discussions as a special volume." Individual reports have been annotated separately.

A.B.S.

165. COGLEY, J.G., and S.B. McCANN. 1976. An exceptional storm and its effects in the Canadian High Arctic. Arctic and Alpine Research 8(1):105-110.

Heavy precipitation fell over the eastern Queen Elizabeth Islands on July 21-23, 1973; 54.6 mm fell at Vendom Fiord, south central Ellesmere Island. The rainfall at Vendom Fiord was associated with a depression which had moved over the rest of the archipelago without producing unusual precipitation. None of the official weather stations in the region reported exceptional amounts, yet there is evidence that the record from Vendom Fiord was representative of a much larger area. The storm was responsible for inundation of flood plains, reworking of coarse alluvium, and rapid mass movements on slopes in the locality of Vendom Fiord, and it is possible that it was the catalyst for a glacier outburst flood (jökulhlaup) which issued from an ice-dammed lake 10 days later. Depressions which impinge upon the mountains of the eastern High Arctic merit futher climatological attention.

A.A.

166. COLBERT, E.H. 1963. Climatic zonation and terrestrial faunas. In: Problems in Paleoclimatology. Edited by: E. A. Nairn. InterScience, New York. pp. 617-637.

The evidence of the terrestrial vertebrates, especially the large ectotherms, is of value in the study of past climates. Upon the basis of such evidence, which of course supplements evidence from other disciplines, it seems probable that during the major extent of geologic history the world was generally tropical and subtropical over much of its surface, and climatic zones were ill defined. ... With the close of Cretaceous times the world entered upon a new phase of climatic history, and during the Cenozoic there was a gradual cooling of climates and an establishment of climatic zones, more sharply defined than they had been in Late Paleozoic and Mesozoic history. These developments are supported by the evidence of mammalian distributions and intercontinental migrations. The process of climatic zonation reached its culmination in the Pleistocene epoch, when mammalian faunas shifted north and south in the northern hemisphere in accordance with the advances and retreats of the continental glaciers...

pA.C.

167. COLEMAN, A.P. 1895. Glacial and interglacial deposits near Toronto. Journal of Geology 3:622-645.

The results of examinations of Pleistocene insect and plant remains from the Scarboro' Heights are detailed. The fauna has a boreal aspect and the flora gives evidence that the climate was like that of the northern part of the Gulf of St. Lawrence or southern Labrador - cool and wet. Investigation of the interglacial deposits along the Don however, indicate a climate as warm as that of Toronto at present, if not considerably warmer. The author attempts a correlation of the results obtained from these two localities and a reconstruction of the postglacial history of the Toronto region.

A.B.S.

168. COLEMAN, A.P. 1933. The Pleistocene of the Toronto region (including the Toronto Interglacial Formation). Ontario Department of Mines, Annual Report, 1932, 41 (Part 7):1-55.

Includes a complete description of Pleistocene geology of the Toronto region. Three sheets of till and two interglacial series have been found in the region: the Wisconsin till, the Sangamon interglacial sand, the Illinoian middle complex of tills and varves, the Yarmouth interglacial Toronto beds, and the Kansan or Nebraskan lowest till. Comments on the climatic conditions at the time of formation is given with the description of each of the many beds.

L.G.

169. COMTOIS, P. 1982. Histoire holocène du climat et de la végétation à Lanoraie (Québec). Canadian Journal of Earth Sciences 19(10):1938-1952.

Four cores from a peat complex at Lanoraie, Quebec have yielded samples of: fossil pollen used for analysis of vegetational history; and oxygen isotopic data indicating climatic variations. The regional vegetation evidently went through the following stages: (1) establishment of a pioneer forest of pine, oak, elm and walnut; (2) development of a sugar maple forest, contemporaneous with migration of beech and correlated with a maximum pollen influx and a climatic optimum at about 3,500 years BP; (3) increase in spruce and fir after 1,500 years BP, related to climatic cooling.

C.R.H.

170. CONNOR, A.J. 1933. Droughts in Western Canada. In: The Canada Yearbook. Acting King's Printer, Ottawa. pp. 47-59.

The author devised a unit Q equal to the 12-month precipitation value, beginning with August 1st, divided by the sum of the temperatures for the months of May, June and July. These are further arranged into a series of progressive quotients which give a graphic history of western weather from the standpoint of soil moisture. The author found the Q values reached a maximum at sunspot minimum, then fell sharply for two years but there was a secondary peak one year before sunspot maximum. Q values fell steeply at the maximum and for a succeeding year when they began to rise slowly back to the peak at the sunspot minima. Since the correlation between weather and wheat yield is poor, sunspots would be of no value in predicting the yield of any particular year.

Thomas

171. CONOLLY, J.R., and M. EWING. 1965. Pleistocene glacial-marine zones in North Atlantic deep-sea sediments. Nature 208(5006):135-138.

North Atlantic deep-sea sediments provide a record of Pleistocene history. Ericson *et al.* (1961) delineated glacial-marine zones "consisting of different Foraminifera assemblages deposited during cold and warm periods of the Pleistocene." By determining the relative abundance of ice-rafted detritus present in the core, the authors were able to define these same zones. Their results indicate "that the abundance and distribution of ice-rafted detritus in deep-sea cores in the North Atlantic could provide a powerful tool for delineating even minor fluctuations in the Pleistocene climate."

A.B.S.

172. COOPE, G.R. 1967. The value of Quaternary insect faunas in the interpretation of ancient ecology and climate. In: Quaternary Paleoecology. Edited by: E.J. Cushing and H.E. Wright, Jr. pp. 359-380.

Insect remains, mostly of beetles, are abundant in Quaternary deposits; any organic silt is likely to yield insect fossils, especially if it contains macroscopic plant debris. These fragments may frequently be matched with modern species; the number of extinct forms is extremely small. With modern ecological requirements of the species as guides, it is possible to postulate ancient environments. Factors are discussed that limit the occurrence of species to particular habitats.

Of particular interest are the climatic factors that determine insect distribution. The response of insects to changes in climate is extremely prompt, because they have a rapid dispersal rate and do not have to wait upon the development of particular soil conditions. Caution must be exercised, however, in the selection of suitable species for climatic interpretation, because many species live in habitats that do not reflect the macroclimate e.g. species that live in heaps of decaying plant refuse.

The climatic implications of insect assemblages are discussed for the Eemian (Sangamon) Interglacial, the Weichselian (Wisconsin) Glaciation, and the postglacial period. Comparison of the occurrence of carabid ground beetles at different altitudes in the Scandinavian mountains with fossil assemblages in Britain has made it possible to infer something of the thermal environment during the glacial summer. The occurrence together in fossil assemblages of species that today seem to be climatically incompatible is discussed, and an attempt is made to reconcile the conflicting evidence.

A.A.

173. COOPER, W.S. 1942. Contributions of botanical science to the knowledge of postglacial climates. Journal of Geology 50(8):981-994.

Botanical science contributes to the knowledge of postglacial climates through inference from fossils and from the distribution of existing vegetation. In the first field the materials include complete plant communities of the past preserved intact and individual plants and plant parts. The bogs of the glaciated region furnish as evidence successive layers of peat of differing character and pollen grains of plants which grew at successive periods. Analysis of the pollen content of the stratified bog deposits is yielding a wealth of evidence concerning post-Pleistocene forest history and therefore as to the concomitant climatic sequence. In inference from present distribution of vegetation, relic colonies of plants are considered as indicators of earlier dominance of types different from those of today and therefore of climatic change. There is almost universal agreement among students of these phenomena that the evidence from fossils and from present distribution indicates a postglacial climatic sequence as follows: from glacial through boreal to a warm and probably dry middle period, followed by a return to the cooler and probably moister conditions of the present. Several nonbotanical lines of investigation provide evidence supporting or consistent with this sequence.

A.A.

174. CORLISS, B.H., A.S. HUNT, and L.D. KEIGWIN, Jr. 1982. Benthonic foraminiferal faunal and isotopic data for the post-glacial evolution of the Champlain Sea. Quaternary Research 17(3):325-338.

Benthonic foraminiferal faunal and isotopic data from Champlain Sea sediments (approximately 12,500 to 10,000 yr B.P. in age) in two piston cores from Lake Champlain provide a detailed, apparently continuous record of the evolution of the Champlain Sea. *Cassidulina reniforme* and *Islandiella helenae* are the dominant benthonic foraminifera during the initial phase of the Champlain Sea, and are replaced by *Elphidium excavatum* forma *clavatum* and *Protelphidium orbiculare* as the dominant species during the remainder of the sea's history. The oxygen-isotopic data show a gradual decrease in $\delta^{18}O$ between approximately 12,500 and 10,900 yr B.P., followed by $\delta^{13}C$ data have a similar trend as $\delta^{18}O$, with generally decreasing values up the section. The isotopic and faunal data suggest that nearly marine conditions were present in the initial phase of the Champlain Sea, followed by gradually decreasing salinities and increasing temperatures as the sea evolved. The beginning of the rapid isotopic decrease at approximately 10,900 yr B.P. marks the onset of the largest environmental change in the history of the Champlain Sea, probably reflecting a major pulse of meltwater from the Laurentide Ice Sheet.

A.A.

175. COX, A. 1968. Polar wandering, continental drift, and the onset of Quaternary glaciation. In: Causes of Climatic Change. Edited by: J.M. Mitchell, Jr. Meteorological Monographs 8(30):112-125.

Continents occupied much of the region around the north pole during the glaciations that occurred in the late Paleozoic and late Cenozoic eras. The geologic evidence is thus at least permissive that polar continentality is a necessary condition for glaciation. However, continents also occupied the polar regions during most of the Paleozoic, Mesozoic and Cenozoic eras at times when glaciation did not occur, so that clearly polar continentality is not a sufficient condition for glaciation. Polar wandering has been linked to the onset of glaciation by several theories which suggest that the glaciation began as the rotation axis migrated toward potential glaciation generating regions such as Antarctica or the Arctic Ocean. These theories are not in agreement with paleomagnetic evidence, which indicates that the rotation axis has been within the present polar region for an interval at least 10 times longer than the interval of glaciation. Similarly, rates of continental drift are too small to permit changes in the configuration of the continents to have played an important role in the onset of Quaternary glaciation. The possibility remains that vertical movements of land masses, many of which occurred at the end of the Pliocene, may have played a significant role in the initiation of Quaternary glaciation.

A.A.

176. CRADDOCK, J.M. 1974. Phenological indicators and past climates. Weather 29(9):332-343.

This paper considers which phenological events, if any, are capable of providing absolute checks on instrumental standards of the earliest meteorological records. The first dates of wine-making for example, may depend on the temperatures of the preceding spring and summer but they may also be determined by changes in the French taste for wine and other non-meterological factors. The best indicator appears to be the first date of grain harvest, followed by the dates of leafing of some trees. The paper compares different phenological diaries especially those of Marsham, Cox and Whistlecraft, outlining their contents and the problems associated with their interpretations. The Royal Meteorological Society's Annual Phenological Report was published from 1875-1947 and then discontinued: this is also described and discussed. A good phenological indicator must correspond to some weather factor which can be quantified, and must not be disturbed by non-meteorological influences.

G.A.

177. CRAIG, B.G. 1959. Pingo in the Thelon Valley, Northwest Territories; radiocarbon age and historical significance of the contained organic material. Geological Society of America Bulletin 70(4):509-510.

Examination of the organic material, largely *Ceratophyllum demersum* and of the pollen assemblage indicates that a warmer climate prevailed. The material has a radiocarbon age of 5,500 ± 250 years. The formation of the pingo may be due to the marked cooling of climate following the thermal optimum.

L.G.

178. CRAIG, B.G., and J.G. FYLES. 1961. Pleistocene geology of Arctic Canada. In: Geology of the Arctic, Volume 1. Edited by: G.O. Raasch. University of Toronto Press, Toronto. pp. 403-420.

Preliminary outline of Pleistocene history of this region, some areas and some parts of the geological record treated in detail, the Cordillera omitted entirely. Continental ice-sheets formerly covered the region except some western Queen Elizabeth Islands, where evidence indicates only local glaciation. Three principal ice-sheets or glacier complexes partly coalesced during their maximum stand; these are called the Wisconsin Laurentide [ice-sheet], the Ellesmere-Baffin glacier-complex, and the Cordilleran ice-sheet. Interglacial deposits are widely distributed in the Mackenzie delta. Gravels, sands, and silts of the late Tertiary or earliest Pleistocene Beaufort formation occupy the western parts of the westernmost islands. These deposits seem to have originated far to the east and southeast; pollen studies indicate the Beaufort formation may form a late stage in the transition from the warm Tertiary to the cool Pleistocene. Large moraines and prominent ice lobes were features of the outermost northwest Wisconsin Laurentide ice-sheet; within the marginal zone, a radial pattern of drumlins, eskers, etc., record the retreat towards the Keewatin ice-divide, which was ice-free about 7,000 years ago. Limit of post-glacial marine submergence increases in elevation from the periphery to the interior of the area covered by the Laurentide ice-sheet. In the northwest, isostatic adjustment was complete before final eustatic rise of sea level 5,000-6,000 years ago. Radiocarbon ages of post-glacial materials are summarized on map and table.

A.B.

179. CRAIG, G.Y. 1963. An ecological approach to the study of fossil marine invertebrates. In: Problems in Paleoclimatology. Edited by: A.E. Nairn. Interscience, New York. pp. 583-590.

A difficulty exists when utilizing faunal evidence for climate reconstruction. ... it may sometimes be overlooked that a faunal assemblage is not quite the same as a fossil population. A variety of causes operate which may result in the addition of exotic elements to an existing population. The result may be confusing. Statistical studies on a single species or a species of a population may well prove rewarding from the climatological aspect - a quite different state of affairs from the use of a key fossil.

Editor

180. CRANE, R.G. 1978. Seasonal variations of sea ice extent in the Davis Strait-Labrador Sea area and relationships with synoptic scale atmospheric circulation. Arctic 31(4):434-447.

Using published data sources for south-eastern Baffin Island, Ungava Bay and the northern Labrador Sea area, a study of the general patterns of sea ice growth and decay has been made for the years 1964 to 1974. From a comparison of individual years an "early" and a "late" pattern of both ice advance and ice retreat are recognised. Mean daily sea-level pressure patterns for June-July and for October-mid-November are examined and a relationship is established between the type of ice advance or retreat pattern and the synoptic circulation over the area. In the years of early ice retreat there is an increased frequency of southerly airflow over the region. Strong winds and the advection of warm air leads to the more rapid removal of the ice compared to years of late ice retreat. Similarly for the years of early ice advance there is an increased frequency of northerly and westerly flow, bringing lower temperatures and an influx of second-year and multi-year ice into the area.

A.A.

181. CRARY, A.P., J.L. KULP, and E.W. MARSHALL. 1955. Evidences of climatic change from ice island studies. Science 122(3181):1171-1173.

An Arctic Ocean ice island T-3 was occupied by the U.S. Air Force from March 1952 until May 1954 for the collection of meteorological, oceanographic, and geophysical data. Cores were taken through the upper part of the island and revealed a large surface dirt layer. Below this layer, in the first 90 feet of ice, there were about 85 dirt layers (although these contained significantly less material than the surface layer), and at 90 feet a heavy dirt layer was found. The ice below this layer, 20 feet cored, was dirt-free. Carbon-14 dating of these dirt layers was utilized in an attempt to reconstruct the island's history. It would appear that the dirt layer began forming following the Climatic Optimum. In the last two hundred years there has been another warm period. The authors believe this historical record has significance for future climatic implications.

A.B.S.

182. CRONIN, T.M. 1976. Late Wisconsin marine environments of the St. Lawrence Lowlands. Geological Society of America, Abstracts with Programs 8(6):825-826.

The late Wisconsin Champlain Sea inundated the isostatically depressed St. Lawrence Lowlands from about 12,500 to 10,000 yr BP. More than 55 foraminiferal and 35 ostracode species have been recovered from deposits in eastern Canada and the United States. Early Champlain Sea faunas, characterized by typically frigid to subfrigid marine assemblages, reflect glaciomarine conditions. ... The relatively diverse foraminiferal assemblage resembles those from recent high latitude seas.

About 11,000 yr BP an abrupt faunal change occurred correlative with a post-Valders retreat of the Laurentide ice sheet. The sea was colonized by a cold temperate, brackish water fauna which included euryhaline marine (*Heterocyprideis sorbyana*), euryhaline fresh (*Ilyocypris gibba, Cyprideis torosa*), and typically brackish (*Cytherura gibba, Cytheromomorpha fuscata, Cythere lutea*) water ostracodes, and a meager eurytopic foraminiferal assemblage dominated by the genus *Elphidium*. Estimated annual water temperatures ranged from 0-20°C; salinities were mostly mesohaline (3-18 ppt). The late Champlain Sea assemblage provides faunal evidence that from 11,000 to 10,000 yr BP: 1) rapid deglaciation of the Laurentide ice sheet following a brief Valders readvance, supplemented by Great Lakes drainage, diluted the sea with large volumes of fresh water; 2) warm Gulf Stream water entered the sea through the Gulf of St. Lawrence; 3) cold temperate conditions existed in the St. Lawrence Lowlands in contrast to synchronous polar-subpolar northwestern Atlantic Ocean conditions at a comparable latitude.

pA.A.

183. CRONIN, T.M. 1976. An Arctic foraminiferal fauna from Champlain Sea deposits in Ontario. Canadian Journal of Earth Sciences 13(12):1678-1682.

A new Champlain Sea fossil locality near Kars, Ontario has yielded at least 41 species of benthonic Foraminifera, 18 of which are recorded from this sea for the first time. Taxonomically the assemblage is almost identical to living faunas from Arctic seas. Paleosalinities of about 30 to 35 ppt and a range of annual paleotemperatures from 0°C to 12°C are indicated by the Foraminifera. A ^{14}C radiocarbon date of 10900 ± 100 a BP (GSC 2312) was obtained from shells of *Hiatella arctica*, suggesting deposition relatively late in the marine episode. The existence of arctic - subarctic environmental conditions at this time in Ontario can be directly attributed to the proximity of the post-Valders Laurentide ice sheet.

A.A.

184. CRONIN, T.M. 1977. Champlain Sea Foraminifera and Ostracoda: a systematic and paleoecological synthesis. Géographie physique et Quaternaire 31(1-2):107-122.

Champlain Sea deposits from Québec, Ontario and the United States yielded over 40 ostracode and 60 benthonic foraminiferal species. Geographical trends in foraminiferal species diversity as measured by the Shannon-Wiener Information Function, H(S), show highest diversities (H(S)=1.6-1.7) in the western Champlain Sea of Ontario, southern Québec and near Québec City, while a significantly less diverse fauna (H(S)=1.0) inhabited the Champlain Valley. Three environmentally distinct phases of the sea based on ostracode species distribution were recognized in the Champlain Valley and southern Québec. An early period, characterized by fresh water and euryhaline marine species, represents a lacustrine-marine transition. Subsequently, frigid to subfrigid, polyhaline to euhaline conditions prevailed. Finally, some time between 11,000 and 10,600 years BP a salinity decrease and a water temperature increase is inferred from the dominance of mesohaline, cold temperate ostracode species. Additional evidence for temporal salinity variations are mean foraminiferal species diversity values which are 1.0, 1.5 and 1.2 respectively for the three phases.

A.A.

185. CRONIN, T.M. 1977. Late-Wisconsin marine environments of the Champlain Valley (New York, Quebec). Quaternary Research 7(2):238-253.

The Champlain Sea occupied the Champlain Valley from about 12,500 to 10,000 yr BP. Following an initial maximum limit of inundation, isostatic crustal rebound caused the sea's gradual regression, which is documented by the parallel alignment of tilted shoreline features at successively lower elevations along a north-south profile. Two new radiocarbon shell dates, 11,665 ± 175 (QC 200), elevation 95 m, and 10,300 ± 180 (QC 199), elevation 47 m, date early and late Champlain Sea deposits, respectively. From the elevation (ASL) and invertebrate fauna of littoral deposits, three environmentally distinct phases of the sea were recognized. Early Champlain Sea Transitional phase deposits at high elevations are characterized by a mixed association of fresh and euryhaline marine ostracodes. Frigid-subfrigid climates and fluctuating salinities of this period possibly reflect intermixing of the fresh waters of Lake Vermont with incoming marine waters. *Hiatella arctica* phase faunas indicate similar climatic conditions but significantly higher salinities (polyhaline). Deposits from the final phase of the sea, the *Mya arenaria* phase, were found at low elevations just above the present level of Lake Champlain. A predominantly cold-temperate, mesohaline fauna characterizes this period. The influences of Lake Algonquin drainage, warm Gulf Stream water and perhaps the retreating Laurentide Ice Sheet are discussed as possible causes for the observed faunal and environmental changes.

A.A.

186. CRONIN, T.M. 1978. Ostracode and foraminifer species diversity in a Pleistocene inland sea. Geological Society of America, Abstracts with Programs 10(2):38.

Fossiliferous deposits of the late Pleistocene (12,500 - 10,000 yr BP) Champlain Sea afford the opportunity to study microfaunal species diversity under the rigorous environmental conditions of an inland sea. Connected with the Atlantic Ocean by a narrow strait, the Champlain Sea inundated 55,000 km^2 of the St. Lawrence Lowlands of Quebec, Ontario, New York, and Vermont. Ostracode and foraminifer assemblages indicate mainly frigid to subfrigid climatic conditions, and paleosalinities that varied from nearly fresh through normal marine conditions.

The ostracode and benthic foraminifer-diversity measures for more than 50 samples included species number (S), the Shannon-Wiener Index (H(S)), and equitability (E). The results show that: (1) A total of 80 foraminifer and 40 ostracode species were found, and, for a given sample, foraminiferal S usually exceeds ostracode S, but H(S) values are comparable; samples yielding high ostracode H(S) also gave high foraminiferal H(S). (2) Throughout most of the sea, H(S) averaged 1.5-1.6. (3) In the narrow arm of the sea, the Champlain Valley, diversity was low (H(S)=1.0). (4) In the Champlain Valley, temporal diversity trends show initially low diversity (H(S)=1.0), then a period of high diversity (H(S)=1.6), and finally another period of low diversity (H(S)=1.0). In general, Champlain Sea S and H(S) values are comparable with those of the present Baltic Sea. The data suggest that the single most important factor influencing microfaunal species diversity in the Champlain Sea was salinity.

A.A.

187. CRONIN, T.M. 1981. Paleoclimatic implications of Late Pleistocene marine ostracodes from the St. Lawrence Lowlands. Micropaleontology 27(4):384-418.

A study of marine and brackish-water ostracodes from Champlain Sea deposits yields data on bottom-water paleotemperatures for three phases of deposition of the sea. The phases are: (1) Transitional (12,500 to 11,600 years BP, frigid climate, -2 to 5-10°C bottom water temperature, oligohaline to mesohaline salinities (0-18 PPT)); (2) *Hiatella arctica* (11,600 to 11,000-10,600 years BP, frigid to subfrigid, 0 to 12°C, polyhaline to euhaline (18-35 PPT)--"normal" marine conditions); (3) *Mya aranaria* (11,000-10,600 to 10,000 years BP, cold temperate, 0 to 20-22°C, diahaline to mesohaline (1-18 PPT)). The significant warming that occurred during the last phase lagged behind the North Atlantic warming, apparently because of the protected nature of the inland Champlain Sea. Also, in the northwestern part of the sea, closer to the Laurentide ice margin, frigid to subfrigid conditions persisted for slightly longer.

C.R.H.

188. CROPPER, J.P., and H.C. FRITTS. 1981. Tree-ring width chronologies from the North American Arctic. Arctic and Alpine Research 13(3):245-260.

A survey of the literature and data filed at the Laboratory of Tree-Ring Research at the University of Arizona reveals 94 tree-ring chronologies of potential use for climatic studies in the North American Arctic. Many of the older chronologies are inadequately replicated, but the geographic coverage in Alaska and the Yukon is good. The chronology statistics indicate their quality is limited and probably less than that of trees from the eastern and western United States sites. Much re-collection is needed to enlarge the chronologies and to extend the common period of overlap with the available climatic data. Future examination of the newer materials will provide a better indication of the true possibilities for climatic calibration and analysis.

A.A.

189. CROSSMAN, E.J., and C.R. HARINGTON. 1970. Pleistocene pike, *Esox lucius*, and *Esox* sp., from the Yukon Territory and Ontario. Canadian Journal of Earth Sciences 7:1130-1138.

Two fish dentaries from Pleistocene deposits in the Old Crow area are referable to *Esox lucius*, the northern pike. They provide the first definite fossil record of the species for North America. The Don Brickyard tooth is older than the Old Crow fossils. It definitely represents an esocid, but we are unable to identify it to species. ... The Yukon fossils tend to confirm the idea that the species was present in the Beringian refugium during the Wisconsin glaciation. Mammal fossils suggest that the environment of the Old Crow area during the late Wisconsin consisted of extensive grassy uplands broken by spruce woodland, with lakes, ponds, and sluggish streams in lower areas. Very likely northern pike lived in the latter type of habitat, where rooted, aquatic vegetation was available.

Since *E. lucius* today has such a wide temperature tolerance we can say only that its presence at Toronto during the last interglacial could well indicate a warm water well-vegetated, lacustrine habitat.

pA.C.+

190. CROWE, R.B. 1958. Recent temperature fluctuations and trends for the British Columbia coast. Department of Transport, Meteorological Branch, CIR-3137, TEC.-228:1-11.

Five-year running averages of mean annual temperature and cumulative percentual deviations of these are plotted for selected British Columbia coast stations. Thirty-year averages and percentual deviations of mean annual temperature are tabulated for the same stations. The same procedure is followed with mean seasonal and mean annual temperature for Agassiz, B.C.

A general rising trend in mean annual temperature of from one to two degrees Fahrenheit over the fifty-year period beginning about 1900 is found for the British Columbia coast. This rising trend is most pronounced in winter and least evident in summer and there is some evidence that the trend may have begun to level off or may have ended. An irregular period of 15 to 20 years between successive major maxima or minima of mean annual temperature is noted. Fluctuations of mean seasonal temperature are more irregular than those of annual values.

Thomas

191. CROWE, R.B. 1960. Recent precipitation fluctuations and trends for the British Columbia coast. Department of Transport, Meteorological Branch, CIR.-3309, TEC.-318:1-4.

Five-year running averages of total annual precipitation are plotted and thirty-year averages of total annual precipitation are tabulated for a number of British Columbia coast stations. The same procedure is followed with total seasonal and annual precipitation for Agassiz, B.C.

No significant decrease or increase in total annual precipitation has occurred over the British Columbia coast during the past half century and a regular period of ten to twenty years between successive major maxima or minima of total annual precipitation is noted. Summer precipitation along the British Columbia south coast was significantly lower during the second quarter of this century than it was during the first quarter.

Thomas

192. CUMBAA, S.L., D.E. MCALLISTER, and R.E. MORLAN. 1981. Late Pleistocene fish fossils of *Coregonus, Stenodus, Thymallus, Catostomus, Lota*, and *Cottus* from the Old Crow basin, northern Yukon, Canada. Canadian Journal of Earth Sciences 18:1740-1754.

Fossils of the broad whitefish (*Coregonus nasus*), inconnu (*Stenodus leucichthys*), longnose sucker (*Catostomus catostomus*), burbot (*Lota lota*), freshwater sculpin (*Cottus sp.*) and Arctic grayling (*Thymallus arcticus*) from a disconformity at locality 15, Old Crow River may date to about 60,000 BP. The fossils could have been deposited in a meandering riverine and tributary stream environment like today's. The fish species represented, consistent with other fossil evidence, indicate climatic conditions similar to the present in early mid-Wisconsin time.

C.R.H.

193. CURRIE, B.W. 1954. Climatic trends on the Canadian Prairies. Agricultural Institute Review 9(1):21-23.

Using data from Winnipeg, Regina and Edmonton, the author showed that one may anticipate over a long period of years higher than average temperature and precipitation for two to four years centred on the years with minimum sunspot activity. The author suggested that the moist conditions that prevailed on the Prairies during the 1870s and the earlier part of this century were exceptional, and that the precipitation during the past 15 years is more nearly typical of the Prairies. Using accumulated heating degree days, he showed that since 1890 at Winnipeg there has been more than a fifteen percent decrease in the amount of fuel required for heating. At Regina, during the months of January, April, July and October, there has been an increase in temperature since 1913. During the past three or four years there has been some indication of a return to cooler conditions. The author believes that a slow extension northward of the Prairies and the northern forests has now started, an extension that could continue for some hundreds or even thousands of years.

Thomas

194. CURRIE, B.W. 1978. The growing season--climatic trends. Institute of Space and Atmospheric Studies, University of Saskatchewan, Saskatoon. pp. 24-42.

While there is some indication that the length of the growing season for the Canadian Prairies as a whole has been decreasing since the late 1960s, this decrease is not evident from the data examined on the length of the frost-free season. The recent downward trend in the length of the growing season may be related to the solar influences studied by Venkatarangan (1978). If such is the case, an upward trend in the length can be anticipated during the next five to six years. However, if the downward trend continues, due to lower average temperatures such as have occurred in the past, the length of the frost-free season will decrease as indicated most conveniently by the median dates for the last spring frost and the first autumn frost.

A.C.

195. CURRIE, B.W., and P. VENKATARANGAN. 1978. Relationships between solar disturbances and the precipitation and temperature on the Canadian Prairies. Institute of Space and Atmospheric Studies, University of Saskatchewan, Saskatoon. 58 pp.

From their investigation the authors are convinced that solar disturbances as indicated by relative sunspot numbers contribute to a variation of Prairie precipitation, the above normal precipitation occurring in several years centered on the sunspot minimum. While period of years of some length have suggested a relationship between solar disturbance and temperature, the presence of a component corresponding to solar disturbances is doubtful. A cycle of about 4 to 5 years appears to be the dominant one. The difference between the maximum and the minimum of the precipitation variation on an average basis is about 3 inches, an amount which can have a significant effect on crop yields.

pA.C.

196. CWYNAR, L. 1978. A late-Quaternary pollen diagram from unglaciated northern Yukon. American Quaternary Association, National Conference, Abstracts 5:162.

A 4-m section of sediment has been retrieved from a lake in a tectonic basin in tundra (68°23'N, 138°23'W) 35 km NE of the Old Crow Flats and 30 km east of the nearest stand of trees. Twelve radiocarbon dates from the upper 3 m indicate a minimum age of 20,000 BP and permit the calculation of sedimentation rates. A dramatic increase in the sedimentation rate between 120-250 cm (13,000-10,000 BP) probably marks the draining of the proglacial lake which occupied the Old Crow Flats. An extrapolation of the sedimentation rate from 250-300 cm to the base of the section suggests that the record may span the past 35,000 years.

A preliminary analysis suggests 3 broadly defined pollen assemblage zones; a basal *Betula*-Cruciferae-Gramineae-*Artemisia* zone, succeeded by a *Betula* zone which is then followed by a *Betula-Alnus* zone. The basal zone, with its high values of

Cruciferae (up to 18%) and low total pollen influx (<50 grains $cm^{-2}year^{-1}$), is interpreted as a discontinuous herbaceous tundra. This herbaceous tundra was replaced by a dwarf birch-willow shrub tundra about 16,000 BP. Alder became widespread at 8,000 BP.

A.A.

197. CWYNAR, L.C. 1982. A late-Quaternary vegetation from Hanging Lake, northern Yukon. Ecological Monographs 52(1):1-24.

A 403-cm core recovered from Hanging Lake in unglaciated northern Yukon dates back to 25,000 and possibly 33,000 years BP, according to 21 radiocarbon dates. From prior to 33,000 to 18,450 years BP, a herb zone (having high percentages of Gramineae, *Artemisia* and Cruciferae) with affinities to modern arctic plant communities was dominant. From 18,450 to 14,600 years BP, a *Salix*-Cyperaceae zone occurred suggesting snowbed and willow scrub communities developed. Between 14,600 and 11,100 years BP dwarf birches spread and the local flora was richer and more diverse - a result of warming climate. From 11,100 to 8,900 years BP, wet heath became locally abundant and spruce became regionally abundant, probably in response to warmer, wetter climate. From 8,900 years BP to the present there was regional expansion of *Alnus crispa*.

C.R.H.

198. CWYNAR, L.C., and J.C. RITCHIE. 1980. Arctic steppe-tundra; a Yukon perspective. Science 208(4450):1375-1377.

The first reliable, securely dated full- and late-glacial pollen stratigraphy from Eastern Beringia forces the rejection of the widely held hypothesis of a steppe-tundra or grassland associated with extinct vertebrates and early humans. The arctic-alpine fossil flora and low pollen influx suggest a sparse tundra similar to modern herb fell-field vegetation.

A.A.

199. DAMON, P.E. 1968. The relationship between terrestrial factors and climate. In: Causes of Climatic Change. Edited by: J.M. Mitchell, Jr. Meteorological Monographs 8(30):106-111.

Large scale crustal warping (epeirogeny) and mountain-building (orogeny) have had a profound influence on the control of climate during geologic time. During periods of maximum transgression of epicontinental seas onto the continents, mild, uniform climates prevail over most of the earth. During periods of maximum regression of the epicontinental seas, climates are cooler and more differentiated. Orogeny is also accompanied by retreat of epicontinental seas and has a similar but shorter-term influence on climate. The time scale of epeirogeny is 250 million years (m.y.), whereas the time scale of orogeny is 40 m.y.

Orogenesis continues during both the regressive and transgressive phase of epeirogeny. It is not by itself a sufficient cause for the onset of continental glaciation. However, when mountain building (orogeny) coincides with maximum continental upwarp during the regressive phase of epeirogeny, continental glaciation ensues. This fact is borne out by the geologic record in Quaternary, late Paleozoic and late Precambrian time. However, the time scale of this "pulse of the earth" is too long to explain glacial-interglacial oscillation.

Volcanic dust and meteoritic impact are important factors in stochastic perturbation of climate which may affect evolution by adding fortuitous calamity to overall climatic stress. However, the geologic record does not justify invoking these factors to explain glacial-interglacial oscillation.

It is probably necessary to call upon astronomic factors to explain these oscillations. The geometric factors invoked by Milankovitch must still be considered and to this must be added

Opik's flickering sun hypothesis. The complex interaction of the sun-earth system leaves little room for confidence in excessively simplistic hypotheses.

A.A.

200. DANSEREAU, P. 1968. Alpine vegetation in eastern North America. Cranbrook Institute Science News Letter 37(8):94-102.

The Ice Age was, in many respects quite adverse to arctic plants. The pollen rain, conserved intact for thousands of years in peat and lake sediments, reveals the shifts in plant dominance throughout the postglacial period. There is little evidence of an initial treeless vegetation in most pollen profiles in eastern North America, even at relatively high altitudes. At the peak of the Ice Age arctic plants must have taken refuge in ice-free areas, either in the unglaciated high Arctic, in the driftless area of Wisconsin, or south of the shifting ice-sheet. Another safety zone was on the now submerged coastline from the Gulf of St. Lawrence to New England and New York. The postglacial climatic fluctuations are documented by present-day distribution of species in both latitudinal and altitudinal zonation presented here.

G.A.

201. DANSGAARD, W., H.B. CLAUSEN, N. GUNDESTRUP, C.U. HAMMER, S.F. JOHNSEN, P.M. KRISTINSDOTTIR, and N. REEH. 1982. A new Greenland deep ice core. Science 218 (4579):1273-1277.

A 2035-m-long ice core was lifted from the south Greenland ice cap at Dye 3 (65°N, 44°W). Comparison of the oxygen isotopic profile with that from Camp Century in northwest Greenland and with a deep-sea foraminifera record indicates that the Dye 3 core reaches back about 90,000 years BP in a continuous sequence. Absolute dating of the core has, so far, reached 3,600 years BP. The core yields valuable paleoclimatic information. As in the Devon Island (Canadian Arctic Islands) ice core, the Wisconsin to Holocene shift in δ is about 7 per mil. The extremely high δs in the silty part of the Dye 3 core (up to 4 per mil higher than mid-Holocene values) suggest a warm period of deposition (Eem/Sangamon interglacial?), probably with lower surface elevations in south Greenland than exist today.

C.R.H.

202. DARBY, D.A. 1975. Kaolinite and other clay minerals in Arctic Ocean sediments. Journal of Sedimentary Petrology 45(1):272-279.

Estimates of clay mineral assemblages in deep-sea cores indicate widespread occurrence of kaolinite throughout the Amerasian half of the Arctic Ocean. Illite is the dominant clay mineral but the kaolinite/chlorite ratio of nearly 1.0 is twice that reported in North Atlantic and North Pacific sediments. Kaolinite averages 26% and is present throughout the lengths of all cores, some of which penetrate 2.8-3.0 m.y. old sediment. The widespread accumulations of kaolinite under conditions apparently unfavorable to its formation has special paleoclimatic significance because it has been used as an indicator of "low latitude" weathering. The kaolinite in Arctic Ocean sediments is apparently derived from shales and "relict" soils of northern Alaska and Canada.

A.A.

203. DAVID, P.P. 1966. The late-Wisconsin Prelate Ferry paleosol of Saskatchewan. Canadian Journal of Earth Sciences 3(5):685-696.

Five occurrences of the Prelate Ferry paleosol are known in exposures in the tributaries of the South Saskatchewan Valley between the Prelate Ferry and Lancer Ferry crossings, in

Saskatchewan. At the reference section, 8 miles north of Prelate, Saskatchewan, the paleosol is best developed, and comprises a very dark brown A_{1b} horizon, 12 inches thick; a grey A_{2b} horizon, 7 inches; a dark brown B_{1b} and a lighter B_{2b} horizon, 12 and 19 inches thick respectively; and a C_b horizon, more than 10 inches thick. The paleosol, a planosol or possibly a solodized-solonetz, developed on the lower till and is buried by 120 feet of sediments comprising two till sheets and three beds of stratified drift. The nonglacial Prelate Ferry interval during which the paleosol formed had a local climate similar to that of today. The beginning of the interval is not known, but it ended about 20 000 years ago, when the last major ice advance occurred in the area. Laboratory examinations indicate that the paleosol is pollen-sterile; it shows an upward decrease in grain size; it is weathered, noncalcareous in most parts; it is slightly to strongly alkaline; and it has a clay mineral content similar to that of the underlying till.

A.A.

204. DAVID, P.P. 1981. Stabilized dune ridges in northern Saskatchewan. Canadian Journal of Earth Sciences 18(2):286-310.

Stabliized dune ridges occurring in northern Saskatchewan have previously been identified as variedly as "ice-crack moraines" and longitudinal dunes. Investigations of their morphological, structural, and sedimentary attributes reveal that they are, indeed, of eolian origin, but they form a particular group within the parabolic dune association, namely, the "Cree Lake type dune ridges". The ridges occur in association with other types of parabolic dunes and other eolian features, such as loess and wind-abraded glacial blocks and bedrock outcrops. The dunes and the associated eolian features, were all formed by southeasterly paleowinds of uniform direction. The dune ridges developed from primary parabolic dunes of simple and composite types through the process of dune elongation. At the same time, exposed rock surfaces were abraded by the wind and loess was deposited downwind from the developing dune fields. The southeasterly direction of the paleowinds, which is almost directly opposite to the direction of the present-day winds affecting dunes in the Lake Athabasca area, was due to adiabatic air masses coming off the ice sheet from the east and affected eolian activity in quite a large region in northern Saskatchewan and Alberta. The somewhat cool and sufficiently dry adiabatic winds checked the vegetation on the dunes and in the areas around them. The development of the dune ridges came to an end when a sudden climatic change evoked the rapid stabilization of the dunes by vegetation but not before most of the ridges became partly deformed by southwesterly crosswinds resulting from the same climatic change. The period of eolian activity is estimated from the age of the local ice frontal positions to have been between 10,000 and 8,800 years BP. Only one other region is known from North America, namely the St. Lawrence Lowland in the east, where analogous eolian environment prevailed in the zone peripheral to the continental ice sheet and produced comparable eolian features.

A.A.

205. DAVIS, M.B. 1967. Late-glacial climate in northern United States: a comparison of New England and the Great Lakes Region. In: Quaternary Paleoecology. Edited by: E.J. Cushing and H.E. Wright, Jr., Yale University Press, New Haven. pp. 11-43.

Pollen assemblages in surface sediments from Canada display geographical correlations with modern vegetation. Pollen deposited within regions of boreal, mixed, and deciduous forest are sufficiently distinct to allow identification of these three vegetational types from fossil pollen assemblages. Further subdivision is possible, since pollen within each type is characteristic for eastern, central, and west-central Canada. Pollen assemblages from tundra far from any forest are different from forest pollen assemblages, but near the tree limit tundra and forest-tundra produce quite similar assemblages.

Comparison with these surface samples indicates that late-glacial pollen sequences from southern New England record a long interval of tundra persisting until about 12,000 years ago. An open spruce woodland developed 10,500 years ago. During the intervening period (12,000-10,500 B.P.) the vegetation may have resembled park-tundra or alternatively, spruce-oak woodland similar to modern vegetation near the prairie in Manitoba. There is no clear evidence for reversals in the general trend of climatic warming at this time. In Nova Scotia a late-glacial pollen sequence resembles modern assemblages in Labrador, and it may record a change from tundra to forest rather than a complete oscillation of vegetation and climate. In the Great Lakes region there was only a narrow belt of tundra vegetation, succeeded by a woodland and forest which may have resembled modern vegetation of the boreal forest and forest-tundra to the north. At the end of late-glacial time, about 10,000 years ago, forest developed in New England similar to modern mixed forest in Ontario; in Minnesota a pine-birch pollen assemblage records a vegetation that may have resembled modern forests of southern Manitoba. Throughout late-glacial and early postglacial time the climate appears to have been cold and relatively continental, without a clearly recorded temperature oscillation correlative with the Allerød of northern Europe.

A.A.

206. DAVIS, M.B. 1969. Palynology and environmental history during the Quaternary period. American Scientist 57(3):317-332.

Pollen grains preserved in sediment provide a record of the terrestrial vegetation surrounding a site of deposition. In southern New England, for example, after the retreat of the ice sheet, tundra changed first to park-tundra, and then to spruce woodland. Before a closed Boreal forest could develop on the landscape, conditions changed to favor a more temperate kind of vegetation. This was a mixed coniferous-deciduous forest like the modern forests of east-central Ontario. Later a temperate deciduous forest became established. With similar information from widely-distributed sites, vegetation changes can be compared over large regions, and the migrations of species can be followed as they expanded northward onto deglaciated landscape. Modern communities can be compared with ancient ones; some plant associations appear to have had a long history, while others are the product of recent adjustments to the postglacial environment. With sufficient geographical coverage we shall be able to evaluate the effect regional vegetation change has had on animal populations, to assess its influence on high extinction rates of mammals, on rapid rates of morphological evolution, and on the rapid development of human culture, that characterize the end of the Ice Age.

A.S.

207. DAVIS, M.B. 1975. Paleoecologic interpretation of pollen deposits. Quaternary Non-marine Paleoecology Conference, University of Waterloo, Waterloo. Program and Abstracts.

Pollen assemblages in modern sediments are correlated with regional vegetation; when these assemblages are identified in ancient sediments, they serve to characterize past vegetation over an entire region, averaged over many kinds of local habitats. Smaller basins, which collect pollen from a smaller area, yield supplementary information, providing data on the history of individual forest stands. Local events, e.g. succession following the blowdown of individual trees, can be followed by this method. By choosing the size of the pollen site, palynologists can obtain information at whatever geographical scale is relevant. Generally regional information is more useful for mapping paleoclimates.

Comparisons of modern influx rates with tree censuses indicate that pollen influx is a direct (although imprecise) measure of population size. Calibration of pollen influx permits direct translation of pollen diagrams into population counts for individual species and genera, extending over many millenia. Climatic interpretations can be based on autecological information rather than regional correlation. Calibration of pollen influx also provides a means for reconstructing ancient plant communities whose pollen assemblages have no modern analog.

A.A.

208. DAVIS, P.T. 1978. Correlation of Holocene moraine stabilization and influx of "exotic" pine and spruce pollen, Cumberland Peninsula, Baffin Island. American Quaternary Association, National Conference. Abstracts 5:163.

Chronologies derived from glacier moraine lichenometric ages and from palynologic sequences recorded in C^{14}-dated peat sections and lacustrine sediments have been used in a study of Holocene climatic change. A lichen growth rate curve for *Rhizocarpon geographicum* s.l. is derived from the work of Miller (1973) and Andrews and Barnett (1978). Dating control for the older part of the curve includes five C^{14} dates on archeological sites and glacial lake shorelines. A general agreement of lichenometric ages of moraine stabilization (end of glacier advance) from three areas of Baffin Island may be observed in the following summary:

SOUTHERN CUMBERLAND PENINSULA (this study) years B.P.	NORTHERN CUMBERLAND PENINSULA (Miller, 1973) years B.P.	BARNES ICE CAP (Andrews & Barnett, 1978) years B.P.	WINDY LAKE PEAT EXOTIC POLLEN (PINE & SPRUCE) INFLUX years B.P.
<400	<200; 350 and 450	200	<100
800-1200	750-900	600-800	700 and 800
	1500-1650	1350 and 1450	1400-1600
1950-2050; 2000-2400	1900-2100	2000 and 2550	2000; 2300-2450
2900-3300	2900-3100	2750 and 3150	2900; 2000-3150
3600 and 3800		4250	3600 and 3750

Palynological data derived from the top 120 cm of the Windy Lake peat section in Pangnirtung Pass are in press (Nichols, Andrews, and Kelley; Andrews, Nichols, and Webber). However, these data have been reinterpreted and additional pollen data have been derived and analyzed from the 127 to 225 cm depth of the Windy Lake peat section. The timing of discrete periods of influx of "exotic" pine and spruce pollen also is noted in the above summary. Presumably, these exotic pollen are carried up to 1000 km from points south to Baffin Island by warm summertime air masses. The correlation (see summary above) suggests that the influx of warm air masses into Baffin Island also is reponsible for the ending of glacier advance and the beginning of glacier retreat (moraine stabilization).

A.A.

209. DAVIS, P.T. 1980. Late Holocene glacial, vegetational, and climatic history of Pangnirtung and Kingnait Fiord area, Baffin Island, N.W.T., Canada. Ph.D. thesis, University of Colorado, Boulder.

In this area, glacier moraine records and lacustrine and peaty sediment sections document complex responses to late Holocene climatic changes.

Studies of modern pollen deposition in surface lacustrine sediments, moss polsters, and Tauber traps allow interpretation of past palynological records in terms of qualitative vegetational changes. Meteorological records and contemporary local and regional pollen were also used to develop transfer functions and to estimate numerical paleoclimatic variations.

Pollen diagrams from the Windy Lake peat are dominated by Gramineae throughout its 3700-year record except for a short-lived *Salix* peak about 2400 years BP. Three sand layers and the cessation of peat growth about 2050-1950, 1700-1450, and 600-0 years BP probably indicate greater cold, but transfer functions suggest that the sand layers may not reflect extremely dry conditions. Exotic tree pollen numbers mirror peaks of total pollen concentration and may indicate slower sediment accumulation, increased vegetation productivity, and/or more intense southerly airflow. Peaks of exotic *Picea* and *Pinus* pollen from the Windy Lake peat do not strongly correlate with dates on moraine stabilization. However, resolution of radiocarbon and lichenometric chronologies are here at the limit of their capabilities.

The dominant pollen taxa from Iglutalik Lake during the last 4000 years fluctuate synchronously and exhibit six peaks at 3950, 3550-3450, 2650, 1800, 1200-1100, and 550 years BP, roughly correlating with periods of glacier retreat. This may have been due to warmer climatic effects. Exotic *Alnus* pollen decreased as exotic *Picea* and *Pinus* increased between 4000 and 3300 years BP at Iglutalik Lake due to warm, southerly, summer winds passing over advancing forests in central Labrador. The transfer function paleoclimatic estimates from Iglutalik and Windy Lake sites show parallels in July temperatures, but contrasts in summer precipitation, possibly due to presence or absence of maritime (sea-ice) effects.

pA.A.

210. DAVIS, R.B., and T. WEBB, III. 1975. The contemporary distribution of pollen in eastern North America: a comparison with the vegetation. Quaternary Research 5:395-434.

By mapping and summarizing 478 pollen counts from surface samples at 406 locations in eastern North America, this study documents the relationships between the distributions of pollen and vegetation on a continental scale. The most common pollen types in this region are pine, birch, oak, and spruce. Maps showing isopercentage contours or isopolls for 13 important pollen types reflect the general N-S zonation of the vegetation. The maps and tabulations of average pollen spectra for the six major vegetation regions indicate high values for the following pollen types in each region: (1) tundra-nonarboreal birch, sedge, and alder; (2) forest/tundra-spruce, nonarboreal birch and alder; (3) boreal forest-spruce, jack pine (type), and arboreal birch with fir in the southeastern part; (4) conifer/hardwood forest-white pine, arboreal birch, and hemlock with beech, maple, and oak in the southern part; (5) deciduous forest-oak, pine, hickory, and elm, with beech and maple in the northern part, and highest values of oak and hickory west of the Appalachian crest; and (6) southeastern forest-pine, oak, hickory, tupelo, and Myricaceae. In some cases, less abundant pollen types are diagnostic for the region, e.g., bald cypress in the southeast. In the conifer-hardwood region and southward, pollen of weeds associated with deforestation and agriculture is abundant. The maps also show that much of southeastern U.S. and the area just to the east of Hudson Bay are in need of additional sampling. At 51 of the sites, absolute pollen frequencies (APF; grains/ml lake sediment) were obtained. These confirm the major conclusions from the percentage data, but differences are evident, e.g., the percentages of alder pollen peak in the tundra whereas alder APFs peak in the boreal forest, and spruce percentages peak in the forest-tundra whereas spruce APFs peak in the boreal forest. Because the APF data reflect the patterns of absolute abundance of individual taxa in the vegetation as well as the overall forest densities, future counts of modern pollen should include APF determinations. The effects of sedimentation processes on APF quantities indicate that APF samples should be obtained from moderate-size lakes of similar morphology and hydrology and that, in each lake, several samples from the profundal zone should be pooled to create a sample representative of that lake.

A.A.

211. DAWSON, Sir J.W. 1893. The Canadian Ice Age: being notes on the Pleistocene geology of Canada, with special reference to the life of the period and its climatal conditions. W.V. Dawson, Montreal. 301 pp.

Two chapters detail the physical and climatic conditions including the causes of glaciation, differential elevation, moraines, ice action, and the distribution of erratics. The author remarks on climatic variations in the glacial age. Temperatures in the early glacial period must have been low; there was a great snow accumulation on the Cordillera and the Laurentian highlands. During the mid-Pleistocene the mean temperature was somewhat lower than at present. The later Pleistocene witnessed great variation in land elevation and corresponding fluctuations in temperature. The author further deduces that our present climate is separated from that of the glacial age by one somewhat warmer. The other chapters in this volume are concerned with historical details, local geographical details, Pleistocene fossils, and general conclusions.

A.B.S.

212. **DELORME, L.D. 1968. Pleistocene freshwater Ostracoda from Yukon, Canada. Canadian Journal of Zoology 46(5):859-876.**

Pleistocene deposits along the Porcupine River, south of the Old Crow basin in the Yukon Territory have yielded 30 species of freshwater Ostracoda. Two of these, *Eucypris foveata* and *Limnocythere liporeticulata*, are new. Certain species within the faunal assemblages are restricted holarctic.

A.A.

213. **DELORME, L.D. 1975. The use of shelled invertebrates in the study of paleoecology. Quaternary Non-marine Paleoecology Conference, University of Waterloo, Waterloo. Program and Abstracts.**

Quantitative and specific distribution of shelled invertebrates are dependent on the physical and chemical limitations imposed by the aquatic habitat in which these organisms live in, which in turn are controlled by geological, hydrological, biological, and climatic factors. Once the nature of these controls has been defined for a region, the ecological limitations of specific ostracodes and molluscs can be determined. Knowing the species tolerance limits then allows one to reconstruct the environments of the past through paleolimnologic, paleoclimatic, and paleohydrologic interpretations.

A.A.

214. **DELORME, L.D., S.C. ZOLTAI, and L.L. KALAS. 1977. Freshwater shelled invertebrate indicators of paleoclimate in northwestern Canada during late glacial times. Canadian Journal of Earth Sciences 14(9):2029-2046.**

Paleoclimatic interpretations based on shelled invertebrates from four sites in the northwest corner of the Northwest Territories, Canada, during the time interval 14,410-6,820 years BP, indicate that the mean annual temperature was about 8.2-11.6°C higher than at present, and that the annual precipitation was about 55-235 mm greater than at the present time. Based on potential evapotranspiration, it can be computed that the length of the growing season was about 156 days long as compared to between 90 and 135 growing days at the present time for the same area.

A.A.

215. **DELORME, L.D., S.C. ZOLTAI, and L.L. KALAS. 1978. Freshwater shelled invertebrate indicators of paleoclimate in northwestern Canada during late glacial times: reply. Canadian Journal of Earth Sciences 15(3):462-463.**

The authors respond to Mackay's (1978) discussion of their earlier paper. "... it is likely that the mean annual air temperatures were in the lower part of the range (-0.4°C) as given by Delorme et al. (1977). This would place the site in a discontinuous permafrost zone where the already existing permafrost could have been preserved, especially in exposed coastal areas, and additional permafrost could have developed in peatlands." The authors note two problems in interpreting quantitative paleoclimatic interpretations.

A.B.S.

216. DENISON, F.N. 1934. Weather cycles on the North Pacific. Proceedings of the 5th Pacific Science Congress 3(A4)23:1785-1787.

The author examined annual precipitation, summer temperature and winter temperature data from stations in British Columbia with the following conclusions. Short-period cycles were discovered in precipitation although the most striking feature was a decrease in precipitation culminating about 1930. Since that time precipitation has been increasing. At Barkerville, a high-level station, there is a secular increase from 1896 to 1920 followed by decreasing precipitation in 1932. Summer temperatures all indicated a secular rise from about the turn of the century to 1928. At Vancouver, this amounted to 3°F. Winter temperatures showed a secular rise since the beginning of records, especially in the north where Atlin exhibited a secular rise from 1906 to 1931 of about 12°.

Thomas

217. DENTON, G.H., and W. KARLÉN. 1973. Holocene climatic variations - their pattern and possible cause. Quaternary Research 3(2):155-205.

In the northeastern St. Elias Mountains in southern Yukon Territory and Alaska, C^{14}-dated fluctuations of 14 glacier termini show two major intervals of Holocene glacier expansion; the older dating from 3300-2400 calendar years BP and the younger corresponding to the Little Ice Age of the last several centuries. Both were about equivalent in magnitude. In addition, a less-extensive and short-lived advance occurred about 1250-1050 calendar years BP (A.D. 700-900). Conversely, glacier recession, commonly accompanied by rise in altitude of spruce tree line, occurred 5975-6175, 4030-3300, 2400-1250, 1050-460 calendar years BP, and from A.D. 1920 to the present. Examination of worldwide Holocene glacier fluctuations reinforces this scheme and points to a third major interval of glacier advances about 5800-4900 calendar years BP; this interval generally was less intense than the two younger major intervals. Finally, detailed mapping and dating of Holocene moraines fronting 40 glaciers in the Kebnekaise and Sarek Mountans in Swedish Lapland reveals again that the Holocene was punctuated by repeated intervals of glacier expansion that correspond to those found in the St. Elias Mountains and elsewhere. The two youngest intervals, which occurred during the Little Ice Age and again about 2300-3000 calendar years BP, were approximately equal in intensity. Advances of the two older intervals, which occurred approximately 5000 and 8000 calendar years BP, were generally less on all four broad expansion intervals; those of the Little Ice Age culminated about A.D. 1500-1640, 1710, 1780, 1850, 1890, and 1916. In the mountains of Swedish Lapland, Holocene mean summer temperature rarely, if ever, was lower than 1°C below the 1931-1960 summer mean and varied by less than 3.5°C over the last two broad intervals of Holocene glacial expansion and contraction.

Viewed as a whole, therefore, the Holocene experienced alternating intervals of glacier expansion and contraction that probably were superimposed on the broad climatic trends recognized in pollen profiles and deep-sea cores. Expansion intervals lasted up to 900 years and contraction intervals up to 1750 years. Dates of glacial maxima indicate that the major Holocene intervals of expansion peaked at about 200-330, 2800 and 5300 calendar years BP, suggesting a recurrence of major glacier activity about each 2500 years. If projected further into the past, this Holocene pattern predicts that alternating glacier expansion-contraction intervals should have been superimposed on the Late-Wisconsin glaciation, with glacier readvances peaking about 7800, 10,300, 12,800, and 15,300 calendar years BP. These major readvances should have been separated by intervals of general recession, some of which might have been punctuated by short-lived advances. Furthermore, the time scales of Holocene events and their Late-Wisconsin analogues should be comparable. Considering possible errors in C^{14} dating, this extended Holocene scheme agrees reasonably well with the chronology and magnitude of such Late-Wisconsin events as the Cochrane-Cockburn readvance (8000-8200 C^{14} yr BP), the Pre-Boreal interstadial, the Fennoscandian readvances during the Younger Dryas stadial (10,850-10,050 varve yr BP), the Allerød interstadial (11,800-10,900 C^{14} yr BP), the Port Huron readvance (12,700-13,000 C^{14} yr BP), the Cary/Port Huron interstadial (centred about 13,300 C^{14} yr BP), and the Cary stadial (14,000-15,000 C^{14} yr BP). Moreover, comparison of presumed analogues such as the Little Ice Age and the Younger Dryas, or the Allerød and the Roman Empire-Middle Ages warm interval, show marked similarities. These results suggest that a recurring pattern of minor climatic variations, with a dominant overprint of cold intervals peaking about each 2,500 years, was superimposed on long-term

Holocene and Late-Wisconsin climatic trends. Should this pattern continue to repeat itself, the Little Ice Age will be succeeded within the next few centuries by a long interval of milder climates similar to those of the Roman Empire and Middle Ages.

Short-term atmospheric C^{14} variations measured from tree rings correlate closely with Holocene glacier and tree-line fluctuations during the last 7000 years. Such a correspondence, firstly, suggest that the record of short-term C^{14} variations may be an empirical indicator of palaeoclimates and, secondly, points to a possible cause of Holocene climatic variations. The most prominent explanation of short-term C^{14} variations involves modulation of the galactic cosmic-ray flux by varying solar corpuscular activity. If this explanation proves valid and if the solar constant can be shown to vary with corpuscular output, it would suggest that Holocene glacier and climatic fluctuations, because of their close correlation with short-term C^{14} variations, were caused by varying solar activity. By extension, this would imply a similar cause for Late-Wisconsin climatic fluctuations such as the Allerød and Younger Dryas.

A.A.

218. DENTON, G.H., and W. KARLÉN. 1977. Holocene glacial and tree-line variations in the White River Valley and Skolai Pass, Alaska and Yukon Territory. Quaternary Research 7(1):63-111.

Complex glacier and tree-line fluctuations in the White River valley on the northern flank of the St. Elias and Wrangell Mountains in southern Alaska and Yukon Territory are recognized by detailed moraine maps and drift stratigraphy, and are dated by dendrochronology, lichenometry, ^{14}C ages, and stratigraphic relations of drift to the eastern (1230 ^{14}C yr BP) and northern (1980 ^{14}C yr BP) lobes of the White River Ash. The results show two major intervals of expansion, one concurrent with the well-known and widespread Little Ice Age and the other dated between 2900 and 2100 ^{14}C yr BP, with a culmination about 2600 and 2800 ^{14}C yr BP. Here, the ages of Little Ice Age moraines suggest fluctuating glacier expansion between AD 1500 and the early 20th century. Much of the 20th century has experienced glacier recession, but probably it would be premature to declare the Little Ice Age over. The complex moraine systems of the older expansion interval lie immediately downvalley from Little Ice Age moraines, suggesting that the two expansion intervals represent similar events in the Holocene, and hence that the Little Ice Age is not unique. Another very short-lived advance occurred about 1230 to 1050 ^{14}C yr BP. Spruce immigrated into the valley to a minimum altitude of 3500 feet (1067 m), about 600 feet (183 m) below the current spruce tree line of 4100 feet (1250 m), at least by 8020 ^{14}C yr BP. Subsequent intervals of high tree line were in accord with glacier recession; in fact, several spruce-wood deposits above current tree line occur bedded between Holocene tills. High deposits of fossil wood range up to 76 m above present tree line and are dated at about 5250, 3600 to 3000, and 2100 to 1230 ^{14}C yr BP. St. Elias glacial and tree-line fluctuations, which probably are controlled predominantly by summer temperature and by length of the growing ablation season, correlate closely with a detailed Holocene tree-ring curve from California, suggesting a degree of synchronism of Holocene summer-temperature changes between the two areas. This synchronism is strengthened by comparison with the glacier record from British Columbia and Mt. Rainier. Likewise, broad synchronism of Holocene events exists across the Arctic between the St. Elias Mountains and Swedish Lapland. Finally, two sequences from the Southern Hemisphere show similar records, in so far as dating allows. Hence, we believe that a preliminary case can be made for broad synchronism of Holocene climatic fluctuations in several regions, although further data are needed and several areas, particularly Colorado and Baffin Island, show major differences in the regional pattern.

A.A.

219. DENTON, G.H., and M. STUIVER. 1966. Neoglacial chronology, northeastern St. Elias Mountains, Canada. American Journal of Science 264(8):577-599.

In the northeastern St. Elias Mountains, Yukon, Canada, drift morphology and stratigraphy, combined with thirteen C^{14} dates, suggest the following Neoglacial and pre-Neoglacial chronology for the Donjek and Kaskawulsh Glaciers: (1) About 12,500 BP (Y-1386) ice of the

Kluane glaciation (=classical Wisconsin by C^{14} dating) receded from near Kluane Lake and about 9780 BP (Y-1483) withdrew behind the position presently occupied by Kaskawulsh Neoglacial moraines. (2) During the Slims nonglacial interval (basically Hypsithermal), glaciers maintained retracted positions; the Kaskawulsh terminus was located at least 13.7 miles up-glacier from its present position. (3) The initial Neoglacial advance, represented by onset of loess deposition, began shortly before 2640 BP (Y-1435). (4) Continuous loess deposition suggests that throughout the Neoglaciation glaciers maintained positions more extensive than those occupied during the Slims interval. (5) The youngest major Neoglacial advance, the most extensive of the last 9780 years (Y-1483), occurred through the last few centuries and is bracketed by seven C^{14} dates. Glacier retreat from this maximum began before A.D. 1874 (Donjek Glacier) and A.D. 1865 (Kaskawulsh Glacier).

Comparison of northeastern St. Elias events with those elsewhere supports the concepts that (1) the initial widespread Neoglacial advance shortly antedated 2600 to 2800 BP and (2) at least some major Neoglacial events were essentially synchronous throughout the Northern Hemisphere.

A.A.

220. DERBYSHIRE, E. 1960. Glaciation and subsequent climatic changes in central Quebec-Labrador: a critical review. Geografiska Annaler 42(1):49-61.

Recent theories on the origin and dissipation of the Laurentide ice sheet suggest the relationship of ice-dispersion centres to precipitation rather than to relief. Assuming the necessary secular drop in temperature, the climatic regime during glaciation is reconstructed in terms of present climatic features. Present climate is the result of two basic factors: geographic position, and relation of the physical character and configuration of the landmass to marine areas. Chief features of oceanic and atmospheric circulation are described; proximity of present climate to glacial conditions (6°-11°F) is estimated. Some late-glacial and postglacial pollen correlations indicate similarity of the climatic history of Quebec-Labrador and the rest of the North Atlantic region.

A.B.

221. Descriptive Palaeoecology. Edited by: A.E.M. Nairn. Interscience, New York. 380 pp. 1961.

Includes a few papers relevant to Canada: geological evidence of cold climate; paleozoological evidence of climate: invertebrates and vertebrates; paleobotanical evidence of climate; and the climatic history of Europe and North America.

L.G.

222. De VRIES, B., and C.D. BIRD. 1965. Bryophyte subfossils of a late-glacial deposit from the Missouri Coteau, Saskatchewan. Canadian Journal of Botany 43(8):947-953.

Bryophyte and associated macro-subfossils were recovered from a kettle located in prairie southwest of Moose Jaw in the Missouri Coteau of southern Saskatchewan. The higher plants were discussed in an earlier paper.

Three samples taken from the organic layer gave C^{14} datings ranging from 11,650 ± 150 to 10,270 ± 150 BP.

Sixteen species and one variety of Musci were recovered. Eleven of these were found in the lowermost zone at a depth of 510-450 cm. This zone was composed of bryophytes and higher plants characteristic of a modern *Picea* forest. Fifteen bryophyte taxa were recovered from the middle zone at a depth of 450-290 cm. The macro-subfossils in this zone are typical of a present-day *Populus-Picea* forest. No bryophytes were found in the upper layer, 290-280 cm characterized by higher plant macro-subfossils and pollen typical of a modern *Picea* forest.

All bryophytes recovered belong to present-day taxa; however, many of the boreal species are not now found in the region as the southern margin of the boreal forest is now 200 miles to the north.

A.A.

223. DILLON, L.S. 1956. **Wisconsin climate and life zones in North America.** Science 123 (3188):167-176.

This paper attempts to reconstruct the climatic and biogeographic conditions that prevailed at the maximum of the last glacial period. To describe the development of the continental ice sheet, the author postulates: (1) an increase in precipitation (beginning in the region of Greenland and northeastern Canada) and; (2) a gradual decrease in mean temperature in the more polar latitudes. At the period of maximum glaciation there appears to have occurred a clinal depression of mean temperature of 25° at the edge of the ice sheet. A series of maps detail the ice sheet's development.

Such glaciation greatly influenced the continent's biota; some palynological and biogeographic data are presented, mainly from the United States. Maps compare present life zones and selected species distributions with those hypothesized for the Wisconsin glaciation.

A.B.S.

224. DIONNE, J.-C. 1975. **Paleoclimatic significance of late Pleistocene ice-wedge casts in southern Quebec, Canada.** Palaeogeography, Palaeoclimatology, Palaeoecology 17(1):65-76.

Ice-wedge casts in southern Quebec are exclusive to deposits pertaining to two ice front positions during the retreat of the Laurentide ice sheet: the Highland front morainic system located at the southern margin of the St. Lawrence lowlands, and the St. Narcisse front morainic system located at the southern margin of the Laurentides highlands. Wedge casts filled with sand and gravel are relic of true ice wedges and give evidence of former permafrost conditions in the ground during the retreat of the ice sheet in that area between 13 000 and 16 000 years BP. Mean annual air temperature was lower than -6°C, a difference of 8-12° with the present-day temperature. Humidity was high enough to allow the growth of ice wedges in the permafrost. These rigorous climatic conditions prevailed during a few centuries only. There is no positive evidence of tundra conditions in southern Quebec younger than 11 000 years ago.

A.A.

225. DIONNE, J.-C. 1976. **Ice-drifted boulders as paleoclimatic indicator, south shore of lower St. Lawrence estuary.** American Association of Petroleum Geologists Bulletin 60(4):664-665. (Abstract).

Ice-drifted boulders are at the surface of the postglacial marine-clay terraces and in raised beaches on the south shore of the St. Lawrence estuary from the present shoreline up to the highest Goldthwait Sea shoreline. They are mainly Precambrian crystalline rocks which were drifted from the north shore of St. Lawrence across a distance of 30 to 55 km. Proportions of crystalline boulders concentrated in modern and ancient beaches and tidal flats range from 60 to 90 percent, but variation is less than 5 percent in neighboring till deposits.

Ice-drifted boulders at the different levels formerly occupied by the Goldthwait Sea show that floating and shore ice were present in the St. Lawrence from the early phases of postglacial submergence until the present.

Mean annual air temperature today in the area considered is 3.3°C at Trois-Pistoles and 2.7° at Pointe-au-Pere, 300 km northeast of Quebec City, with 5 months with a mean temperature below 0°, mean temperature for January being respectively -11.8 and -10.8°. Shore and floating ice are present from December to April.

Since the retreat of the Laurentide ice sheet the climate in the Lower St. Lawrence Estuary probably was similar to the present one with possibly some colder and warmer phases; however, it was cold enough to allow freeze-up and ice drifting of boulders from the north shore to the south shore of the estuary. In absence of other evidence in sediments, ice-drifted boulders could be a valuable indicator of a temperate climate with cold winter.

A.A.

226. DONAHUE, P.F., and T. HABGOOD. 1974. Analysis of the pollen and spore rain at two archaeological sites on the Nechako Plateau, British Columbia. Syesis 7:93-99.

Pollen and spore analysis of surface and subsurface samples taken from the vicinity of two archaeological sites [Ulkatcho, believed to have been permanently occupied shortly before 1793 and abandoned by 1945; Tezli, believed to have been initially occupied as early as 2000 B.C. (S-769 3850 ± 140; 1900 B.C.)] in the central plateau of British Columbia indicate little if any change in the vegetation pattern within the time period represented by the sediments sampled. All levels included, in order of decreasing frequency, *Pinus, Picea, Alnus, Abies, Tsuga*, and *Salix*. Local hydrological fluctuations are reflected in changes in the herbaceous components.

Other than the reflection of local hydrological changes, there is no evidence for climatic change over the time period represented by the sediment trap profile. Our 38 cm profile was sampled at 3.8 cm intervals ...

A.A.+

227. DONN, W.L., and M. EWING. 1968. The theory of an ice-free Arctic Ocean. In: Causes of Climatic Change. Edited by: J.M. Mitchell, Jr. Meteorological Monographs 8 (30):100-105.

On the basis of IGY and post-IGY data and interpretations, the original Ewing-Donn model of the Arctic Ocean control of glacial-interglacial stages has been modified. According to the revision, the importance of the ice-free Arctic Ocean is in the initiating of high-latitude glaciation followed by glacial growth to lower latitudes in those regions where an adequate moisture supply is present. The Arctic Ocean surface would freeze once a good-sized peripheral ice sheet formed and would have no direct effect in the nourishment of continental ice sheets thereafter. A glacial stage is terminated, not by the decrease of Atlantic Ocean sea level below the Iceland-Faroe-Scotland sill (Wyville Thomson ridge) but by the decreased atmospheric moisture supply consequent upon the lowered temperature of the Atlantic Ocean. Geologic data interpretable in terms of ice thickness seem to support the theory of an Arctic source of moisture of the growth of high-latitude ice sheets in North America and Siberia. Geologic evidence from field observations on land and from the analysis of cores from the deep sea indicate that glaciation commenced well before the beginning of the Pleistocene. When considered together with uncertainties attached to the precise time of the migration of the geographic north pole into the Arctic basin, the earlier problem of the lag between the time the paleomagnetic pole became centered in the Arctic and the beginning of glaciation is diminished considerably.

A.A.

228. DONN, W.L., and D. SHAW. 1975. The evolution of climate. In: Long-term Climatic Fluctuations, World Meteorological Organization, WMO-421. pp. 53-64.

A quantitative evaluation is made of the climatic effects of polar wandering plus continental drift in order to determine whether this mechanism alone could explain the deterioration of climate that occurred from the warmth of Mesozoic time to the ice age conditions of the late Cenozoic.

G.A.

229. DORF. E. 1960. Climatic changes of the past and present. American Scientist 48 (3):341-364.

Traces climatic changes during the Cenozoic era (mainly on paleobotanical evidence) and considers future trends. Late Eocene fossils indicate: subtropical forests in southeastern Alaska; a warm temperate forest belt from central Alaska to central Greenland, Spitsbergen and Siberia; subarctic, boreal forest on Ellesmere Island (at 82°30'N). Pleistocene fossils record northern plants and animals south of present limits, e.g. musk oxen in southern United States. The present interglacial warming trend is expected to continue for two centuries, with probable return to another glacial stage in 10,000-15,000 years. Indications (several from the Arctic) of warmer climate during the past century are cited. Contrary to the general trend, some areas, e.g. the Hudson Bay region are becoming cooler.

A.B.

230. DREDGE, L.A. 1982. Relict ice-scour marks and late phases of Lake Agassiz in northernmost Manitoba. Canadian Journal of Earth Sciences 19(5):1079-1087.

In northern Manitoba, intersecting grooves 300-1800 m long are ice-scour marks created by the dragging of iceberg keels along rises in the bed of a glacial lake whose water plane was at about 305 m asl. The lake was bounded by glacial ice on its northern and eastern margins. The occurrence of scours on topographic divides indicates that a single extensive lake, thought to be a northern extremity of Lake Agassiz, occupied the area as far north as Seal River at the time the ice scours were formed. The lake extended as far west as Sprott Lake and eastwards into the Hudson Bay Lowlands into an area later occupied by Tyrrell Sea. The preservation of the scour marks suggests that the lake drained suddenly.

Ice-scour marks are easily recognized on air photographs and provide a means of identifying areas that have been inundated by glacial lakes. Scours in emerged marine sediment are generally obliterated by littoral processes.

A.A.

231. DREIMANIS, A. 1953. Two late Wisconsin interstadial deposits from Ontario, Canada. Geological Society of America Bulletin 64(12):1414. (Abstract).

Of the two deposits, one is from the shore of Lake Erie 9 miles west of Port Stanley, Ontario; it consists of lacustrine silt and gyttja and is covered by two till beds which up to now have been correlated with the lithologically similar early and late Cary tills of northern Ohio. C^{14} date of the gyttja (10,900 ± 400) suggests a later age - the Two Creeks interval - for this interstadial deposit. Pollen analysis reveals the existence of forests along Lake Erie consisting principally of jack-pine and spruce.

The other deposit is from North Bay and consists of a peat bed covered by a thin layer of very bouldery till. Pollen analysis records growth of birch, hemlock, pine, spruce, fir, oak (in a descending order of importance) and some elm, linden, beech and alder. The results of pollen analysis suggest that the peat was deposited during the postglacial thermal maximum or slightly later.

If the C^{14} dating of the first interstadial deposit is correct, the retreat of Wisconsin ice from Ontario was later than assumed by most Pleistocene geologists, with Mankato ice twice occupying the Lake Erie basin and a readvance of ice down to North Bay during the "little ice age" after the postglacial thermal maximum.

A.A.

232. DREIMANIS, A. 1967. Mastodons, their geologic age and extinction in Ontario, Canada. Canadian Journal of Earth Sciences 4(4):663-675.

Most Canadian occurrences of mastodons are from southern Ontario. About four-fifths of them have been found below Lake Warren shore, thus being younger than 12 400 years B.P.; the youngest radiocarbon date is 8 910 ± 150 years B.P. Though most mastodons entered Ontario after the retreat of the Wisconsin ice sheet, a few occurrences may belong to the Mid- and Early Wisconsin interstadials. Association of spruce pollen with mastodon bones and concentration of mastodons in the poorly drained lacustrine plains during the late-glacial and early postglacial time suggest that mastodons preferred spruce forest or woodlands. The extinction of mastodons might have been initiated by gradual shrinking of these spruce forests, and completed by their disappearance from southwestern Ontario, owing to increasing warmth and dryness of postglacial climate, and improvement of drainage along the lowered Great Lakes. Mastodons did not find their way to the northern boreal spruce forests, being separated from them by a wide belt of pine and hardwood forests, which meanwhile had developed over the better drained morainic areas of southern Ontario. Weakened by less suitable food, mastodons became more sensitive to diseases and an easier prey to the Paleoindians.

A.A.

233. DREIMANIS, A. 1968. Extinction of mastodons in eastern North America: testing a new climatic environmental hypothesis. Ohio Journal of Science 68(6):257-272.

More than 600 late Wisconsin mastodon occurrences are known from the glaciated and periglacial portions of eastern North America. Most of them have been found in poorly drained lowlands, swamps, and valleys, and on the continental shelf. Of the 28 radiocarbon-dated mastodon bones or associated wood from the entire area of eastern North America, 80 percent are 9,000-12,000 years old. Spruce forests or open woodlands have been indicated by palynologic investigations of 18 mastodon sites; wood or cones of spruce and trees associated with spruce forests have been found at ten sites.

This evidence and the distribution pattern of mastodons near the northern boundary of the area of their occurrences suggest that the mastodons of eastern North America were associated with open spruce woodlands or spruce forests. Their extinction was probably initiated by the rapidly increasing dryness 10,000-11,000 years ago, which caused first the retreat of the spruce forests into the moister lowlands and finally their disappearance from the area occupied by mastodons. A migration of mastodons from the relict spruce enclaves toward the more northerly located spruce forests was hampered because these two areas were probably separated by a rapidly expanding belt of pine and hardwood forests over the better-drained morainic, kame, and dune areas in the Great Lakes Region.

A.A.

234. DREIMANIS, A., and P.F. KARROW. 1972. Glacial history of the Great Lakes - St. Lawrence region, the classification of the Wisconsin(an) stage, and its correlatives. 24th International Geological Congress, Section 12:5-15.

Major glacial advances and retreats in the Great Lakes - St. Lawrence region suggest a natural division of the Wisconsin(an) Stage into three substages: Early, Middle and Late Wisconsin(an). A more detailed classification can be developed best in the St. Lawrence - Lake Ontario - Lake Erie - Lake Huron region, as here ice marginal positions can be correlated with levels of the proglacial lakes which depended upon opening and closing of their outlets by glacial retreats and readvances. In the northeastern portion of the region a correlation with sea level changes is also possible. Abundant radiocarbon dates have been obtained on non-glacial material and the glacial chronology is inferred. Step-by-step tracing in the field, and lithologic, textural and fabric analyses of tills have greatly assisted in correlations. Climatic interpretations have been based on the fossil record, particularly palynologic data.

All the above information permits subdivision of the three Wisconsin(an) substages into several stadials and interstadials and phases and intervals, by using already established names (St. Pierre, Port Talbot, Plum Point and Erie Interstadial) and introducing new ones, particularly for the glacial stadials and phases.

The proposed classification of the Wisconsin(an) Stage in the Great Lakes - St. Lawrence region compares well with deep-sea and Greenland ice core paleotemperatures, and general glacial histories of the northern hemisphere.

A.A.

235. DREIMANIS, A., J. TERASMAE, and G.D. McKENZIE. 1966. The Port Talbot interstade of the Wisconsin Glaciation. Canadian Journal of Earth Sciences 3(3):305-325.

The Port Talbot interstade is a cool, long, nonglacial interval separating the Early from the Late or Main Wisconsin in the Lake Erie region. Recent test borings at its type locality, lithologic and palynologic investigations of the cores, and new radiocarbon dates suggest that this interval was considerably longer than previously assumed. It began more than 48 000 years before present (B.P.) and ended, if the Plum Point interval is included, 24 000 years B.P.

The entire nonglacial interval comprises two relatively warm episodes, with boreal climate (Port Talbot I and II), separated by a brief glacial readvance that reached Lake Erie from the north; 100 varves were deposited during this readvance. Another similar readvance separates the Port Talbot I beds from the Plum Point (?) sands and silts. Pine (*Pinus*) and spruce (*Picea*) pollen predominate throughout the section, with relative abundance of oak (*Quercus*) in the Port Talbot I green clay. The pollen assemblages are dissimilar from those of the Sangamon interglacial or postglacial in southern Ontario.

A.A.

236. DUMANSKI, J. 1969. Micromorphology as a tool in Quaternary research. In: Pedology and Quaternary Research. Edited by: S. Pawluk. University of Alberta Press, Edmonton. pp. 39-52.

Soil fabric consists of both relatively stable and relatively mobile constituents. In studying such material in thin section, the soil morphologist attempts to determine the nature of soil in its undisturbed state, and endeavours to explain the observed dynamics in terms of the physical and chemical environment in which soil is forming.

Soil process is very often reflected in the manner of organization of soil plasma which, in turn, constitutes a reflection on the environment of soil formation. Investigations spread over most of the world have established that there is a dependence among fabric type, solid profile characteristics, and environmental conditions. Such information can often be of considerable use in Quaternary research, but its proper application is highly dependent on a detailed knowledge of presently important soils, their associated microfabrics, and corresponding environmental conditions. Microfabrics of soils found in the Northern Great Plains are discussed.

Excerpt

237. DUNBAR, M.J. 1946. The state of the West Greenland Current up to 1944. Journal of the Fisheries Research Board of Canada 6(7):460-471.

Temperature records from the mouth of Godthaab fjord, west Greenland, during 1942-1944, show a cooling of the water over these three years, particularly marked in the first half of the year. The temperature history of the West Greenland Current is traced by means of available records since 1883. It is found that warmer conditions existed during the decade of 1880, followed by a colder period up to about 1920, when the present warm period began. The peak of the present warm period appears to have been reached in the middle 1930s, and it is possible that the cycle is about to return to colder conditions, with a weakening of the Atlantic component of the current.

A.A.

238. DUNBAR, M.J. 1954. A note on climatic change in the sea. Arctic 7(1):27-30.

As both temperature and northward water transport has increased in the north Atlantic, the author reasons that this must be balanced by an increased flow of polar water southward implying that the polar outlets east of Greenland and in the Canadian eastern Arctic should show less climatic change than other areas in the north Atlantic regions during the past 35 years. The author states that this happened both in the recent warming period ending about 1940, and in the short warm period which occurred in the 1880s. The effect of the 1915-45 period has been comparatively unimportant in the Canadian eastern Arctic, but there is evidence that the effect was stronger in the 1880s. The author concludes that if the present relaxation of the Atlantic circulation gives way in due course, to an increase in circulation again, which is probable, a northward transport of heat to a degree greater than the recent warm period will occur. We might look forward to a time when the cold upper layer of Polar water in the Arctic Ocean is finally washed out. If and when that happens the climate of the north will no doubt become suddenly considerably milder and moist.

Thomas

239. DUNBAR, M.J. 1955. The present status of climatic change in the Atlantic sector of northern seas, with special reference to Canadian eastern Arctic waters. Transactions of the Royal Society of Canada 49(3):1-7.

A review and discussion "to draw attention to certain aspects of the shorter cycle of variation in the sea." The influence of these climatic changes is demonstrated by the fluctuations in certain fish populations.

A.B.S.

240. DUNBAR, M.J. 1959. Arctic marine zoogeography. In: Problems of the Pleistocene Epoch and Arctic Area. Compiled by: G.R. Lowther. Publications of McGill University Museums (Montreal) No. 1:55-63.

The author traces the marine history of the Pleistocene in the north from analysis of deep-sea sediment cores. The results of Wiseman (1954) "show a steadily increasing temperature from a date approximately 13,500 years ago to a maximum about 5000 years ago, followed by a gradual decline to the present time. This is in agreement with climatic information obtained by other methods. Along the path of this decline there have been oscillations, shorter periods of milder climate which have interrupted the overall cooling. The most recent of these mild periods appears now to be at its peak or just past it, probably the latter, and it has had drastic effects on the zoogeography of the northern seas...". The author compares glacial and postglacial patterns and faunal elements with those of the present.

A.B.S.

241. DUNBAR, M.J. 1968. Ecological Development in Polar Regions: A Study in Evolution. Prentice-Hall, Englewood Cliffs, New Jersey. 119 pp.

"We shall be examining the responses to the Pleistocene demands and challenges mainly in terms of ecosystem development, ecosystemlimitation, and geographic distribution. Our purpose is to put Arctic life in its evolutionary perspective and to demonstrate that the Arctic has problems for life which extend considerably beyond ice, snow, and cold water."

Chapter 3 (pp. 28-36) entitled "The Pleistocene Event" describes changes in the climate. There is a short review of some of the evidence and theories put forward in an attempt to explain environmental changes. Pleistocene climatic oscillations and the possible effects of future changes are also mentioned in Chapter 8, "Rehearsal and Discussion".

L.G.

242. DUNBAR, M.J. 1972. Increasing severity of ice conditions in Baffin Bay and Davis Strait and its effect on the extreme limits of ice. In: Sea Ice Conference Proceedings. Edited by: T. Karlsson. Reykjavik. pp. 87-93.

Warming trends in the Northern Hemisphere in the 1920s and 1930s came to an end in the 1940s, with falling temperatures thereafter. Ice conditions, according to the author should reflect the same trend with a bit of lag and the change might first become noticeable in the boundary areas of the ice covered waters. This is a fact in Greenland and the paper documents the same trend in Baffin Bay and Davis Strait using air reconnaissance data for the 1950s and 1960s. Mapped results illustrate that ice conditions in the areas studied were markedly more severe in the 1960s than the 1950s. According to the author it is reasonable to assume that the deterioration of ice conditions will continue for at least another two decades. "One point of great interest in the Baffin Bay data is the smallness of the variation in maximum extent of ice. ... A similar stability of the ice limit has been noted in the Bering Sea, and the contrast with conditions in the Greenland Sea, where the outer limits seem to react so sensitively to climatic change, is quite striking". Records of the Danish Meteorological Institute (1901) and accounts of whalers and explorers are included in the study.

"We have thus an ice limit that fluctuates considerably along the west coast of Greenland, but apparently varies little across Davis Strait, though this is not fully proved". Possible reasons are advanced. It seems that Davis Strait contains three types of ice limits, i.e. those where a warm northerly current flows towards the ice, those where a cold southerly current flows away from the ice and those where the current flows along the ice edge. On the east side the formation of ice is limited by the heat transported by the West Greenland current, while on the west the ice is carried far to the south on the cold Labrador current to the east coast of Newfoundland; these two limits vary considerably. The ice edge in the centre of Davis Strait runs parallel to the current direction, though it does not constitute the southern limit of ice formation but rather the flank of a southward moving stream. The author suggests that the controlling factor is also the contiguity of a warmer water mass in which ice can neither form nor long survive.

The author feels that "the total ice production in Baffin Bay should be greater rather than less in warming periods, because more ice will form to replace that carried out on the increased current. It will however presumably melt more quickly in the warmer waters farther south, thus reducing the amount of fluctuation in the extreme ice limit and perhaps forming to some extent a self-regulating system. Whether the faster-moving, faster-forming ice will represent a net increase in ice volume is less clear, as it will presumably be less thick than the ice forming in the slower-moving pack of the cold period. This factor too should be to some extent self-regulating, and the net volume may not vary very much. "These speculations, however, apply more to maximum, or winter, conditions than to summer".

L.G.

243. DUNBAR, M.J. 1973. On the west Greenland sea-life area of the Atlantic salmon. Arctic 26(1):3-6.

During the 1960s salmon appeared in the region west of Greenland. The author attributes this to marine climatic change; "the warming period in West Greenland came to an end and signs of a return to colder conditions appeared." Migration and navigation of the salmon are discussed.

A.B.S.

244. DUNBAR, M.J. 1976. Climatic change and northern development. Arctic 29(4):183-193.

The warm decades in the early part of the present century were replaced by a cooling trend from 1940 to about 1970, followed by the suggestion of a reversal in the past five years. The most complete record of these changes in northern sea areas is to be found in West Greenland where whole ecosystems moved north then retreated south. During the recent warming trend, the southern limit of sea ice in the Svalbard - Jan Mayen region retreated 200-300 km northward between 1928 and 1936, and then moved south again during the cooling period. The need for a means of predicting ice conditions is becoming acute. On land, faunal changes have accompanied the changes of climate. The changes in the potential for agriculture, aquaculture and stock breeding are important for northern development. Prediction of these changes of climate is the crucial need.

G.A.

245. DUNBAR, M.J., and D.H. THOMSON. 1979. West Greenland salmon and climatic change. Meddelelser om Grønland 202(4):5-19.

Climatic variations affecting the West Greenland marine region since the 16th century are reviewed in association with historical records of the Atlantic salmon (*Salmo salar* L.) in that area. There is evidence that the salmon, which are very abundant at present during their sea-life in West Greenland waters, were also present in some numbers in the years around 1600 and 1810. In all three periods the marine climate was cooling, following a warming phase. A possible hydrographic mechanism for this effect is suggested in the alternation of a strong zonal (west-east) climatic system over the North Atlantic region, giving warmer conditions in West Greenland, and periods of weakening of this zonal system and the appearance of anomalous easterly winds in South Greenland. The latter cause East Greenland Current water and Irminger Current water to increase in transport in the formation of the West Greenland Current, and are associated with a southward movement of the Iceland Low and a reduction in pressure gradient between the Iceland Low and the Azores High.

A.A.

246. DYCK, W., and J.G. FYLES. 1963. Geological Survey of Canada radiocarbon dates. Geological Survey of Canada Paper 63-21:1-31. (reprinted from Radiocarbon 4:13-26; 5:39-55.)

Title self-explanatory.

C.R.H.

247. DYCK, W., and J.G. FYLES. 1964. Geological Survey of Canada radiocarbon dates. Geological Survey of Canada Paper 64-40:1-15. (reprinted from Radiocarbon 6:167-181.)

Title self-explanatory.

C.R.H.

248. DYCK, W., J.G. FYLES, and W. BLAKE, Jr. 1965. Geological Survey of Canada radiocarbon dates. Geological Survey of Canada Paper 65-4:1-23. (reprinted from Radiocarbon 7:24-46.)

Title self-explanatory.

C.R.H.

249. DYCK, W., J.A. LOWDEN, J.G. FYLES, and W. BLAKE, Jr. 1966. Geological Survey of Canada radiocarbon dates. Geological Survey of Canada Paper 66-48:1-32. (reprinted from Radiocarbon 8:96-127.)

Title self-explanatory.

C.R.H.

250. DYLIK, J. 1964. Le thermokarst, phénomène négligé dans les études du Pléistocène. Annales de géographie 73(399):513-523).

Distinguishes between the chemical erosion of extra-arctic karst processes and the physical changes of thermokarst in permafrost zones, where the melting of ground ice is a basic factor in thermokarst. Two main types of development, generally caused by climatic warming, and local in very cold regions, are described. Evidence of thermokarst is provided by patterned ground, solifluction phenomena, cave-in or thaw lakes, etc. Current research discloses more on recent thermokarst phenomena than on fossil thermokarst from the Pleistocene, though general belief is noted in the existence of a warm interval which caused the ice to melt. Thermokarst structures and processes help in determining the paleogeography of the Pleistocene, and provide important paleoclimatic evidence.

A.B.

251. DZERDZEEVSKII, B.L. 1969. Climatic epochs in the twentieth century and some comments on the analysis of past climates. In: Quaternary Geology and Climate. Edited by: H.E. Wright, Jr. Proceedings VII Congress INQUA, Volume 16 (National Academy of Sciences, Publication 1701, Washington). pp. 49-60.

For the reconstruction of past climates the synchronisation of tree-ring measurements and pollen samples, obtained from isolated and usually distant points, is very important. However, the analysis of climatic data and dynamic processes and their relationships with other geographical components is of even greater importance. Some results of such investigations are discussed in this paper. The existence of two climatic epochs in the 20th century is described. A meridional circulation prevailed during the first epoch, and a zonal one during the second. The beginning of a third epoch in the 1950s is confirmed. The change of temperature and precipitation and noticeable reaction of the vegetation to those climatic fluctuations was observed.

G.A.

252. EATON, G.P. 1963. Volcanic ash deposits as a guide to atmospheric circulation in the geologic past. Journal of Geophysical Research 68(2):521-528.

Infers information on the direction of upper air winds for various periods from deposits of windborne volcanic ash. The direction of the long axis of a given deposit is approximately parallel to the vector resultant wind experienced by the falling ash. A map of 24 Recent ash deposits, both terrestrial and marine, from the eruptions of Mt. Spurr, Mt. Katmai in Alaska, Bezymyannyy in Kamchatka, and others shows excellent agreement with the observed circulation of the lower atmosphere. Studies of Ordovician, Permian, Cretaceous, and Tertiary ash deposits probably would yield data for construction of a planetary circulation map for those periods.

A.B.

253. EDDY J.A. 1977. Climate and the changing sun. Climatic Change 1(2):173-190.

Long-term changes in the level of solar activity are found in historical records and in fossil radiocarbon in tree-rings. Typical of these changes are the Maunder Minimum (A.D. 1645-1715), the Spörer Minimum (A.D. 1400-1510), and a Medieval Maximum (c. A.D. 1120-1280). 18 such features are identified in the tree-ring radiocarbon record of the past 7500 years and compared with a record of world climate. In every case when long-term solar activity falls, mid-latitude glaciers advance and climate cools; at times of high solar activity glaciers recede and climate warms. We propose that changes in the level of solar activity and in climate may have a common cause: slow changes in the solar constant, of about 1% amplitude.

G.A.

254. EDMONDS, T.C., and C.H. ANDERSON. 1960. Note on climatic trends in the Lower Peace River region of northern Alberta. Canadian Journal of Plant Science 40(1):204-206.

"There are two major climatic factors determining the type of agriculture for any region: precipitation, and temperature together with associated phenomena. The long-term averages and trends of these factors are important in determining the future agricultural activities of a specific area." The authors document the trends that have developed in annual precipitation, mean annual temperature and killing frost-free period at Fort Vermilion. These trends are evident despite large year-to-year fluctuations. Total annual precipitation shows a decided increase during the last 50 years. Over this period there has been a 3°F rise in mean annual temperature. Similarly the trend in killing frost-free period shows an increase "from the 10-year average of 81 days in the period 1909-1918 to an average of 101 days in the period 1949-1958. This large increase has a marked bearing on varietal and crop usage."

A.B.S.

255. EK, C., C. HILLAIRE-MARCEL, et B. TRUDEL. 1981. Sédimentologie et paléoclimatologie isotopique dans une grotte de Gaspésie, Québec. Géographie physique et Quaternaire 35(3):317-328.

The object of the study is a cave known as "Spéos de la Fée", at La Rédemption. Developed by flowing water in Silurian limestones to the west of Lac Matapedia, its present morphology is influenced by collapse features near the two entrances. In the principal passage-a dip tube-water-lain silt and fine sand deposits are overlain by a diamicton containing clasts of various lithological composition, and amongst them striated limestone pebbles. The isotopic composition of the carbonate fraction of the sediments ($\delta\ ^{13}C$ and $\delta\ ^{18}O$) indicate that these fragments are derived directly from the bedrock. A stalactite dated at 7355 ± 190 BP (UQ-101) was analysed for its composition in ^{13}C and ^{18}O. The results were then compared to the isotopic composition of present day carbon dioxide and water in the cave. The conclusions were reached that the precipitation of carbonates ($\delta^{13}C$ = $-6^{0}/_{00}$ and $\delta\,^{18}O$ = $-10^{0}/_{00}$) occurred in equilibrium with water derived mainly from snow melt. The ^{18}O values of the concretion thus reflect winter precipitation conditions.

A.A.

256. ELIAS, S.A. 1982. Holocene insect faunas from two sites at Ennadai Lake, Keewatin, Northwest Territories, Canada. Quaternary Research 17(3):371-390.

Ennadai Lake, in the forest-tundra ecotonal region of Keewatin, Northwest Territories, Canada, has been the subject of several paleoecological investigations (palynology, plant macrofossils, fossil soils). This study concerns Holocene insect fossils at Ennadai, a new approach in a region shown to be sensitive to climatic change. The Ennadai I site yielded 53 taxa, representing 13 families of Coleoptera and 7 families of other insects and arachnids, including abundant ants. These fossils range in age from about 6300 to 630 yr B.P. The Ennadai II site produced fossils of 58 taxa, including 13 beetle families and 15 families of other arthropods, ranging in age from 4700 to 870 yr B.P. The insect evidence suggests the presence of trees in the Ennadai region from 6000 to 2200 yr B.P. A conifer pollen decline from 4800 to 4500 yr B.P. at Ennadai has previously been interpreted as an opening up or retreat of forest in response to climatic cooling, but the insect fossils reveal the continued presence of trees during this interval. Both insect assemblages suggest trends of forest retreat and tundra expansion between about 2200 and 1500 yr B.P., presumably due to climatic cooling, with a return of woodland by about 1000 yr B.P.

A.A.

257. ELSON, J.A. 1969. Late Quaternary marine submergence of Quebec. Revue Géographie de Montréal 23(3):247-258.

About 220,000 km^2 of Quebec was submerged mainly during the deglaciation of the last 13,000 years. This resulted from slow isostatic uplift of the crust concurrent with eustatic rise of sea level. The earliest submergence was in the Gulf and the St. Lawrence estuary from about 13,000 to 10,000 years ago. The Champlain Sea occupied the upper St. Lawrence and Ottawa valleys from about 12,000 to 10,000 years ago and was succeeded by the smaller Lampsilis Lake which was drained prior to 7,000 years ago. The Lake St. John area was flooded by the Laflamme Sea from about 10,300 to 8,700 years ago. Marine submergence of valleys and narrow parts of the coast in the Ungava Bay regions occurred from 8,000 to 6,000 years ago. The coast of Hudson and James bays was extensively inundated from about 7,000 to 3,000 years ago. Crustal uplifts ranging from 150 to 275 m have occurred since deglaciation, generally at rates of from 5 to 10 m per century for the first 2,000 to 4,000 years. Eustatic rise of sea level exceeded the rate of uplift roughly 10,800 years ago, sometime between 6,000 to 8,000 years ago, and about 5,000 years ago, resulting in local temporary regression and transgression of the sea. Fossils reflect conditions of salinity and temperature in the submerged areas.

A.A.

258. ELSON, J.A. 1969. Radiocarbon dates, *Mya arenaria* phase of the Champlain Sea. Canadian Journal of Earth Sciences 6(3):367-372.

The history of the Champlain Sea is divided into an early cold period of subarctic water termed the *Hiatella* phase that lasted from its inception about 11 800 years ago (Two Creeks time), until a low water phase about 10 800 years ago (Younger Dryas or Valders time). This was followed by an interval of warmer boreal water, here called the *Mya arenaria* phase, that lasted from about 10 800 years ago until 10 000 years ago or the end of the Champlain Sea.

General descriptions, previously unpublished, of Groningen dates GrN 2031 (10 870 ± 100 B.P.), GrN 2032 (10 450 ± 80 B.P.), and GrN 2034 (10 590 ± 100 B.P.), and GrN 2035 (10 330 ± 100 B.P.) are presented. These dates record the *Mya arenaria* phase of the Champlain Sea, which may have had an initial rising (transgressive) phase, though the stratigraphic evidence, supported by three sets of radiocarbon dates, is not wholly conclusive.

A.A.

259. **EMERSON, D. 1983. Late glacial molluscs from the Cooking Lake moraine, Alberta, Canada. Canadian Journal of Earth Sciences 20(1):160-162.**

Several species of freshwater mollusc, with radiocarbon dates of 10 900 - 9050 years BP, have been recovered from supraglacial and intraglacial lacustrine sediments in the Cooking Lake moraine region of south-central Alberta, Canada. The organisms indicate the onset of a warming trend in the region that lasted at least 2000 years, marking the final stages of melting in the continental Wisconsin ice sheet.

This period of climatic amelioration coincides with a similar trend in southwestern Alberta during the time interval 13 000 - 9000 years BP based also on the evidence of late and early postglacial molluscan communities.

A.A.

260. **EMILIANI, C. 1955. Pleistocene temperatures. Journal of Geology 63(6):538-578.**

Through oxygen isotopic analyses of Foraminifera from Atlantic, Caribbean, and Pacific deep-sea cores, the author obtains temperature records.

"In one Pacific core which extends to the Pliocene, the 610-cm level below top is believed to represent the Plio-Pleistocene boundary. About fifteen complete temperature cycles occur above this level, and the length of Pleistocene time is estimated at about 600,000 years. ...

"Closely spaced samples from short pilot cores furnish a detailed temperature record for postglacial times. A continuous temperature increase from about 16,500 to about 6,000 years ago is indicated, followed by a small temperature decrease. The temperature maximum at about 6,000 years ago is correlated with the "Climatic Optimum". ...

"Good correlation exists between times of temperature minima as indicated by extrapolated rates of sedimentation and times of insolation minima in high northern latitudes. Control of world climate during the Pleistocene by insolation in the high northern latitudes is indicated. A retardation of about 5,000 years occurred between temperature and insolation cycles." The author explains the glacial epoch and its ages by a theory combining topographical and insolation effects. He believes a new ice age may begin in about 10,000 years.

A.B.S.

261. **EMILIANI, C. 1971. The last interglacial: paleotemperatures and chronology. Science 171(3971):571-573.**

The O^{18}/O^{16} analysis and Th^{230}/Pa^{231} dating of deep-sea cores showed that the last interglacial age, with an early major temperature maximum followed by two smaller ones, extended from 100,000 to 70,000 years ago and was preceded by a glacial age extending from 120,000 to 100,000 years ago. The O^{18}/O^{16} analysis and Th^{230}/Pa^{231} dating of speleothems confirm and refine these ages.

A.A.

262. **EMILIANI, C., and W.F. LIBBY. 1976. First Miami conference on isotope climatology and paleoclimatology. Eos 57(11):830-836.**

This conference included papers on solar neutrinos and the isotopic record from the ocean floor, tree-rings, speleothems and fossil waters, geochronology and the Brunhes epoch and radiocarbon and global climate. The major problem area was identified as the rate and frequency of climatic change, the study of which is a prerequisite for achieving precise climate prediction.

G.A.

263. **ENGLAND, J. 1976. The maximum advance of the Greenland ice sheet onto northeastern Ellesmere Island and subsequent events. American Quaternary Association, Abstracts 4:138.**

Previous field work on northeastern Ellesmere Island indicated that the Greenland Ice Sheet had formerly advanced onto the eastern margin of the Hazen Plateau. Evidence for this advance was based on the presence of red granite erratics overlying the sedimentary rocks of the Franklin Geosyncline. In 1975 a 20 km, east to west transect was made across central Judge Daly Promontory, northeastern Ellesmere Island, at a point 25 km across from the westernmost shore of Greenland. The upper limit of granite erratics in this locality clearly reflects a former extension of the Greenland Ice Sheet onto Ellesmere Island. This advance, however, is suprisingly limited and many upland surfaces along this transect extend above the till which is the uppermost and oldest glacial event observed in the area. Periglacial rock weathering on some of the unglaciated summits has evolved from bedrock through massive blockfields to coarse frost hummocks and homogenous mats of travertine-coated rock chips (2-4 cm in length). Weathering of the bedrock in the zone of the Greenland till is also considerable (oxidation >1m, tors >2m) and, surrounding the tors, both the felsenmeer and thick accumulations of colluvium are incorporating the sparse granite erratics. The granite erratics are commonly characterized by frost shattering and active granular exfoliation. One amino-acid date from shells in an ice-contact terrace (marine till) in the zone of the Greenland advance tentatively dates at 80,000 - 160,000 B.P. and a peat palsa has accumulated in the adjacent spillway.

Subsequent to this there occurred the maximum advance of the northeastern Ellesmere Island ice out to Robeson Channel. Lateral moraines from this advance cross-cut the Greenland till at lower elevations and represent a thin, topographically-controlled ice terminus which floated and calved-off in the isostatically-depressed embayments along Robeson Channel. Evidence for such ice shelves are present in two major valleys adjacent to Robeson Channel where sharply descending kame moraines suddenly become horizontal for several kilometers. There ice shelves suggest relative sea levels ca. 160-200 m above present. Weathering of the Cape Rawson sandstone, a widely distributed erratic in this region, suggests that these moraines predate the last glaciation. Five samples of shells associated with these ice-shelf moraines and proglacial marine sediments indicate ages >35,000 B.P. based on the amino-acid dating method whereas one ^{14}C date on corresponding material is 29,700 ± 5400 B.P. In addition, bedded sands overridden by this advance contain the locally extinct species *Dryas octopetalla*. No Greenland ice advance onto Ellesmere Island is in evidence following the deposition of the outermost Ellesmere Island glacial till. Evidence from the Quaternary stratigraphy on northeastern Ellesmere Island suggests that several weathering zones of widely differing ages exist in the area. These surfaces are relevant to the understanding of past glacial activity in the High Arctic, and consequently to the interpretation of ice cores, the existence of refugia and paleoclimatic reconstructions.

A.A.

264. **ENGLAND, J. 1976. Late Quaternary glaciation of the eastern Queen Elizabeth Islands, N.W.T., Canada: Alternative models. Quaternary Research 6(2):185-202.**

It has been suggested that during the last glaciation the Innuitian Ice Sheet existed over the eastern Queen Elizabeth Islands. This is based on the pattern of postglacial emergence over this area and the timing of driftwood penetration into the interisland channels. Alternative interpretations of both sets of data raise questions about the presence of the Innuitian Ice Sheet at this time. Field observations on northeastern Ellesmere Island, plus additional data pertaining to the presence of multiple tills and "old" radiometric dates on lacustrine deposits, shelly tills, and raised marine features suggest that the maximum glaciation over this region, equivalent to the Innuitian Ice Sheet, predates the last glaciation. Palaeoclimatic conditions are also discussed in relation to these data.

It seems reasonable to suggest.... that maximum glaciation over the Queen Elizabeth Islands, equivalent to the Innuitian Ice Sheet, was attained when a meridional circulation pattern had generally unrestricted access into the arctic archipelago. It is questionable, therefore, that the Laurentide and Innuitian maxima were contemporaneous. It is more likely that their buildup, in time, was out of phase.

It is suggested that during the last glaciation of the Queen Elizabeth Islands there was a convergent but not coalescent advance of the existing upland icefields. This noncontiguous ice cover over the Queen Elizabeth Islands is termed the Franklin Ice Complex. It is suggested that the term Innuitian Ice Sheet be reserved for contiguous older glaciations over this same area.

A.A.+

265. **ENGLAND, J., and R.S. BRADLEY. 1978. Past glacial activity in the Canadian High Arctic. Science 200(4339):265-270.**

Field observations on northeast Ellesmere Island indicate that the maximum advance of the northwest Greenland Ice Sheet was 100 kilometers beyond its present margin. This occurred before the outermost Ellesmere Island ice advance, which took place more than 30,000 years before present (B.P.). Recession from the Ellesmere Island ice margin began at least 28,000 to 30,000 and possibly more than 35,000 years B.P. During this sequence of glacial events, significant land areas remained free of ice. The late Wisconsin ice extent along both northeast Ellesmere Island and northwest Greenland was extremely limited, leaving an ice-free corridor along Kennedy and Robeson channels. Recession from these ice margins is indicated by initial postglacial emergence around 8100 to 8400 years B.P. The relatively minor extent of late Wisconsin ice in the High Arctic probably reflects a period of extreme aridity occasioned by the buildup of the Laurentide Ice Sheet to the south.

A.S.

266. **EPSTEIN, S., and R.P. SHARP. 1959. Oxygen-isotope variations in the Malaspina and Saskatchewan Glaciers. Journal of Geology 67(1):88-102.**

Reports oxygen-isotope analysis of ice and firn samples collected in 1953-1954 from these glaciers in Alaska and Canada. The method of analysis is described; and the data, tabulated and graphed, are discussed as to the possibility of using oxygen-isotope relations as natural tracers in glaciers. The O^{18}/O^{16} ratios in the samples varied with the climatic environment in which the ice originated; ice from higher latitudes and altitudes had lower ratios. In Malaspina Glacier, ice originating in the upper Seward Basin had a higher O^{18}/O^{16} ratio than material supplied from higher mountain slopes bounding the basin. Oxygen-isotope data confirm a former hypothesis that the deformed and thinned bands of ice in the outer part of the glacier represent individual valley glaciers separated by medial moraines.

A.B.

267. **ERICSON, D.B., M. Ewing, and G. Wollin. 1964. Sediment cores from the arctic and subarctic seas. Science 144(3623):1183-1192.**

Presents a reconstruction of the Pleistocene climate of the Arctic Basin and Greenland Sea based on study of 58 cores from the former and 26 from the latter. A similarity of depositional processes between them and the Atlantic is revealed. The fluctuation in numbers in *Globigerina pachyderma* tests, indicate climatically controlled variations in the thickness and continuity of the arctic ice cover. Coiling direction of *Globigerina* suggests a northward shift of the 7.2°C isotherm at the end of the last glacial, and that the isotherm has never extended into the Norwegian Sea in the past 70,000 years. Ice movements in the area are also reconstructed.

A.B.

268. ERICSON, D.B., M. EWING, G. WOLLIN, and B.C. HEEZEN. 1961. Atlantic deep-sea sediment cores. Geological Society of America Bulletin 72(2):193-286.

Studies of lithology, particle-size distributions, and micropaleontology and chemical analyses of 221 Atlantic and Caribbean deep-sea cores lead to new conceptions of processes of sedimentation, rates of sediment accumulation, Pleistocene chronology, and pre-Pleistocene history of the Atlantic basin.

Variations in the planktonic Foraminifera in 108 of the cores and extrapolation of rates of sediment accumulation determined by 37 radiocarbon dates in 10 cores show that the last period of climate comparable with the present ended about 60,000 years ago. A faunal change indicating climatic amelioration, probably corresponding to the beginning of postglacial time, occurred about 11,000 years ago. Cross-correlations by micropaleontological methods establish the continuity of the climatic record deduced from the planktonic Foraminifera. Study of variation in the planktonic Foraminifera leads to a different Pleistocene chronology from that proposed by Emiliani (1955).

pA.A.

269. EWING, M. 1960. The ice ages theory. Journal of the Alberta Society of Petroleum Geologists 8(7):191-201.

Presents oceanographic evidence for a major climatic change 11,000 yrs. ago, which terminated the last ice age; and postulates conditions which may have caused glacial and interglacial periods during the Pleistocene.

A.B.

270. EWING, M., and W.L. DONN. 1956. A theory of ice ages. Science 123(3207):1061-1066.

Contains "a preliminary report of new ideas related to the origin of glacial climates" based on 20 years' observations. It is postulated that "some mechanical process has caused the poles to migrate to positions very favorable for the development of glacial climates". The changes during the Pleistocene are assumed to have resulted from alternations of ice-free and ice-covered states of the Arctic Ocean caused by polar dislocation from its freely circulating to enclosed areas. The same mechanism could explain similar climatic changes in early epochs. The theory complies with the doctrine of uniformitarianism and claims no external or catastrophic events.

A.B.

271. EWING, M., and W.L. DONN. 1960. On Pleistocene surface temperatures of the North Atlantic and Arctic Oceans. Science 131(3393):99.

Authors propose two additional interpretations to Ericson's hypothesis on the coiling directions of *Globigerina pachyderma* and their relation to Pleistocene North Atlantic temperatures: a hypothesis based on water mass distribution and a thermal node concept.

A.B.

272. EWING, M., and W.L. DONN. 1961. Pleistocene climate changes. In: International Symposium on Arctic Geology, Proceedings. Edited by: G.O. Raasch, University of Toronto Press, Toronto. Volume 2. pp. 931-941.

Discusses the ice-free condition of the Arctic Ocean as the direct cause of the Pleistocene glaciation in the Northern Hemisphere. Evidence indicating an open Arctic Ocean during the Pleistocene is found in studies of air temperature gradients, postglacial uplifts, arctic seismicity, and the overall heat budget of the arctic area. Glacial-interglacial stages of the Pleistocene are explained by an oscillating meteorological model, which provides a direct source for the large snow accumulation in the regions around the Arctic Ocean and for alternating ice-free and ice-covered states of the ocean itself. Southern Hemisphere glaciation, except for Antarctica, is explained as the result of global cooling produced by the extensive glaciation in northern regions.

A.B.

273. EWING, M., and W.L. DONN. 1963. Polar wandering and climate. Society of Economic Paleontologists and Mineralogists, Special Publication 10:94-99.

Abundant evidence indicates an open Arctic Ocean during the Wisconsin glacial stage; the ice-free ocean is believed directly responsible for this glaciation. Alternating ice-free and ice-covered states of the Arctic would account for oscillations of Pleistocene climate. Climatic oscillations in the Northern Hemisphere produced similar variations in the Southern Hemisphere; the Antarctic icecap however, probably persisted through the entire Pleistocene. The cooling which began in the Oligocene and culminated in the Pleistocene is attributed to a shift of the geographic poles from an open, freely circulating ocean environment to their present thermally isolated positions.

A.B.

274. EWING, M., W.L. Donn, and W. Farrand. 1960. Revised estimate of Pleistocene ice volume and sea-level lowering. Geological Society of America Bulletin 71(12), part 2:1861. (Abstract).

Studies in the Canadian Arctic Islands, Siberia, and Greenland suggest that the Pleistocene ice sheets were thicker and covered a greater area than hitherto supposed. The estimate of glacioeustatic fall in sea level (-300 ft.) is revised: -400 to -500 ft.

A.B.

275. EYLES, N. 1977. Late Wisconsinan glacitectonic structures and evidence of postglacial permafrost in north-central Newfoundland. Canadian Journal of Earth Sciences 14(12):2797-2806.

Rhythmically-bedded glaciofluvial sediments deposited subaqueously and now exposed on an emerged coastal foreland in north-central Newfoundland, exhibit postdepositional deformation structures such as synclinal folds and faulted zones of ground collapse, the result of melting of underlying buried glacier ice. A high rate of glaciofluvial deposition is indicated. The development of fault systems in those sediments overlying decaying glacier ice can be compared with laboratory simulations of vertical foundering in sedimentary rocks. Ice-wedge casts transecting folded and faulted sections in the area are indisputable evidence of subsequent permafrost conditions, i.e. a period when mean annual air temperatures lay below -6°C. A rise of at least 10.4°C in mean annual air temperature is indicated since that time. A severe periglacial climate is considered to have existed in the area from 12000 to 10000 years BP and ice wedges developed with a minimum growth rate of 1.25 mm/year. Comparison with reports of ice-wedge casts in Nova Scotia and the west coast of Newfoundland indicate that the period which they formed in north-central Newfoundland may be correlated with the tundra pollen zone L-3 of Livingstone and Livingstone, the Greatlakian substage of the Late Wisconsinan in Midcontinental North America.

A.A.

276. FAIRBRIDGE, R.W. 1972. Climatology of a glacial cycle. Quaternary Research 2(3):283-302.

A "glacial cycle" is defined as a major global climatic oscillation of the order of 10^5 yr, developed within an "ice age" *sensu lato* which may last 10^6-10^7 yr and which recurs at widely spaced intervals in geologic time (ca. 2 x 10^8 yr). The ice age situation thus only persists during 5-10% of all geologic time and is preconditioned by geotectonics and *not* by extraterrestrial controls.

The repetitive nature of the glacial cycle is demonstrated by independent records from (a) glacigenic, ice-melt deposits, i.e., tills and fluvioglacial terrace accumulations; (b) eolian by-products, i.e., loess; (c) marine terraces and beach deposits, eustasy inversely reflecting the ice volumes; and (d) deep-sea deposits, biologically and lithologically reflecting the climatic events. Only the marine section offers a continuous, uninterrupted record. Different chronometric techniques confirm a major cycle of the order of 10^5 yr (eight repetitions in the last 700,000 yr), but there are multiple types of modulation, in part related to self-accelerating feedback, either negative (retardation) or positive, leading to acceleration.

Within any given cycle there is an Interglacial, Anaglacial, Pleniglacial and Kataglacial phase, characteristics of which are repeated on a small scale in minor cycles. Their timing is variable in a latitudinal sense, apparently steered by radiation changes that first affect the tropics.

Interglacials are defined in their classical stratotype areas of NW Europe, by sedimentary sequences characterized by the pollen of deciduous forests, pointing to climates at least as warm as those of the present time. The present cycle began ca. 10,000 YBP, with the start of the Holocene epoch, and the contemporary warm phase is seen as a typical interglacial stage. Such warm peaks characteristically last about 10,000 yr. Symptoms of the expected ensuing glaciation range from a global fall in temperature since mid Holocene, to tropical desiccation (growth of deserts) and high latitude retreat of tree lines.

A.A.

277. FAIRBRIDGE, R.W., and C. HILLAIRE-MARCEL. 1977. An 8,000-yr palaeoclimatic record of the 'Double-Hale' 45-yr solar cycle. Nature 268(5619):413-416.

A series of isostatically-emerged Holocene beach ridges on the east side of Hudson Bay have been precisely surveyed and dated back to 8,300 BP. They number 185 and show a nearly uniform rhythm of about 45 yr correlated here with the 'Double-Hale' solar magnetic cycle. (Time is in sidereal yr.) Longer correlations are suggested with eustatic sea-level curve and with planetary conjunction cycles. The coupling mechanism with terrestrial meteorological behaviour is believed to be by means of stratospheric generation of polar cirrus cloud and low-latitude ozone, affecting the planetary albedo.

A.A.

278. FALCONER, G. 1966. Preservation of vegetation and patterned ground under a thin ice body in northern Baffin Island, N.W.T. Geographical Bulletin 8:194-200.

A thin ice body in northern Baffin Island is undergoing rapid recession revealing undisturbed patterned ground features and vegetation. A sample of moss thus exposed has a radiocarbon age of 330 ± 75 years, and supports previous estimates of the occurence of a markedly more nival period in parts of arctic Canada two to three centuries ago.

A.A.

279. **FALCONER, G., J.T. ANDREWS, and J.D. IVES. 1965. Late Wisconsin end moraines in northern Canada. Science 147(3658):608-610.**

A system of end moraines nearly 2240 kilometers long has been identified by field investigations and aerial photography. It extends through northeastern Keewatin, Melville Peninsula, and Baffin Island and marks the border of a late-Wisconsin ice sheet centered over Foxe Basin and Hudson Bay 8000 or 9000 years ago.

A.A.

280. **FALCONER, G., J.D. IVES, O.H. LØKEN, and J.T. ANDREWS. 1965. Major end moraines in eastern and central Arctic Canada. Geographical Bulletin 7(2):137-153.**

A system of end moraines more than 2,000 km long, has been identified by field investigation and from air photographs. It runs parallel to the northeast coast of Baffin Island approximately along the line of the fiord heads; it extends down the west coast of Melville Peninsula and across northern Keewatin and demarcates the border of a late-Wisconsin ice sheet that was centred over Foxe Basin and Hudson Bay between 8,000 and 9,000 years ago. The various units of the system are described, and related radiocarbon dates are discussed. A tentative correlation with the Cochrane Readvance and with moraine units in northwestern Ontario and in the Lake Athabasca-Cree Lake area is made. The names "Cockburn Glacial Phase" and "Cockburn Moraine System" are proposed for use on a regional scale; this involves a redefinition of the Cockburn moraines of northeast Baffin Island as originally proposed by Ives and Andrews (1963).

A.A.

281. **FIEUX, M., and H. STOMMEL. 1975. Preliminary look at feasibility of using marine reports of sea surface temperature for documenting climatic change in the Western North Atlantic. Journal of Marine Research 35 (Supplement): 83-95.**

The nature and quality of sea-surface temperature (SST) records for 20°-40°N 50°-60°W have been examined to determine their suitability for historical analysis of SST, and for evidence of climatic variation. The data demonstrate, using six-year means for individual months, a warming from 1910-1920 to a maximum in 1950-1960, and thereafter a cooling.

G.A.

282. **FILLON, R.H. 1975. Deglaciation of the Labrador continental shelf. Nature 253(5491): 429-431.**

This study, which used 1,100 km of deep-towed 3.5 kHz sparker profiles, 1,200 km of side-scan sonar records, 2,000 km of echo sounding profiles and 165 bottom sediment samples collected during cruises of CSS Dawson and CFAV Sackville has identified moraines and other relict glacial land forms on the outer Labrador Shelf.

Faunal evidence indicates a warming of ocean water in the eastern Arctic region beginning before 8,000 yr BP. The Cockburn-Cochrane readvance of closely similar age has been interpreted to be the result of a glacial surge to a new equilibrium profile in response to rapid deglaciation of a part of Hudson Bay. It is therefore tempting to speculate that the retreat of ice from the seaward edge of Hamilton Bank occurred at about the same time as the opening of Hudson Bay and that both areas were deglaciated in response to a general warming of the ice sheet. The ensuing readvance on Hamilton Bank is seen as an adjustment to a new equilibrium profile and as a corollary to the Cockburn-Cochrane event.

A radiometric deglacial chronology for south-eastern Labrador has not yet been established. Deglaciation dates of 16,000-14,000 yr BP have been inferred for the Labrador Shelf, but published and unpublished ^{14}Cdates from the Ha[illegible] Inlet area are consistently younger than 8,700 yr BP. These dates and the probable triggering effect of the climatic warming imply that deglaciation of the Labrador Shelf may have been in progress as late as 9,000 yr BP.

Excerpts

283. FILLON, R.H. 1976. The Sangamonian/Wisconsinan transition in the Labrador Sea. Geological Society of America, Abstracts with Programs 8(6):864.

Cores from the northern and eastern Labrador Sea are correlated with dated shard zones (9K and 65K) from the North Atlantic (Ruddiman and Glover, 1972). The longest core (Hu 75-42) from 62°40'N, 53°55'W and 2400 m w.d. appears to have a nearly constant sedimentation rate. It was examined at 1.6K intervals through the Sangamonian/Wisconsinan transition. Comparison with trigger cores as well as faunal, isotope and % CO_3 paleotemperature curves from other areas has demonstrated that high radiolarian and diatom numbers consistently signify warm episodes while *N. pachyderma* behaves reciprocally throughout much of the section. Based on extrapolated ages, there appears to be a very close correspondence in time and sign between oscillations in the radiolarian abundance curve of Hu 75-42 and paleotemperature curves from the Gulf of Mexico and the Caribbean. This suggests that contemporaneous oceanographic changes occur in arctic and tropical water masses with the advent of climatic deterioration. These events appear to be masked in some intermediate areas and anomalous water bodies such as the ice lowered Arctic Ocean. The spread of ice across channnels in the Arctic Archipelago would have effectively blocked the Arctic Ocean source of cold, low salinity Labrador Current Water. This would have, at least initially, retarded winter sea ice development while allowing increased surface cooling and associated O_2 enriched bottom water formation. This could have caused a deepening of the lysocline and may be reponsible for an increase in preserved *N. pachyderma* tests during the climatic transition. Abundant diatoms throughout the core imply an absence of any long lasting perennial ice cover during the Wisconsinan.

A.A.

284. FILLON, R.H., and J.C. DUPLESSY. 1980. Labrador Sea bio-, tephro-, oxygen isotopic stratigraphy and late Quaternary paleo-oceanographic trends. Canadian Journal of Earth Sciences 17(7):831-854.

A stratigraphic framework for eastern Labrador Sea cores has been developed for the interval 0-90,000 years BP through analysis of oxygen isotopes, volcanic ash, benthonic foraminifera, and the radiolarian *Diplocyclas davisiana*. Benthonic and planktonic foraminiferal isotope stratigraphy and the time scale of Shackleton and Opdyke provide a basis for the approximate dating of a series of marker events which include ash zones at ca. 59,000 and < 21,000 years BP; benthonic foraminiferal abundance maxima at ca. 83,000, 75,000, 60,000, 19,000, and 3,000 years BP; and *D. davisiana* percentage maxima at ca. 90,000, 73,000, 64,000, 54,000, 45,000-32,000, and 10,000 years BP. Incursions of subpolar planktonic foraminifera into the area during parts of isotopic stage 2 (between about 13,000 and 25,000 years BP but probably excluding the 15,000-18,000 years BP glacial maximum interval) and during the isotopic stage 4/5a transition (around 75,000 years BP) suggest that the eastern Labrador Sea was free of sea ice, at least in summer during periods of rapid continental ice sheet growth which lead to the isotopic stage 4 and stage 2 glacial maxima. A larger than normal stage 1/stage 2 difference in the isotopic composition of benthonic foraminifera (1.8 $^0/_{00}$) implies that this open water and attendant surface cooling was a potential source for colder than modern deep water. In contrast the Norwegian Sea was a reservoir of warmer than modern deep water during the last glacial.

A.A.

285. FISHER, D.A. 1979. Comparison of 10^5 years of oxygen isotope and insoluble impurity profiles from the Devon Island and Camp Century ice cores. Quaternary Research 11(3):299-305.

Oxygen-isotope profiles for the Devon Island ice cap and Camp Century Greenland are affected by a number of variables, some of which must have been the same for both sites. The two δ (^{18}O) records spanning about 120,000 years are brought into relative alignment by comparison of major δ features, and subsequent verification that the insoluble particulate concentration records were also in phase for this alignment. The difference between the δ profiles is shown to be mainly a function of the altitude of the accumulation area for Camp Century. This altitude seems to have been higher than present for the last 100,000 years, suggesting the present flow line through the site has never been shorter. The maximum altitude for the Camp Century accumulation area is 1500 m above the present site and is almost synchronous with the maximum in particulate concentration that occurs at 16,000 yr B.P. The synchronism is likely due to the maximum sea-level lowering that exposed vast areas of continental shelf to wind erosion.

A.A.

286. FISHER, D.A., and R.M. KOERNER. 1981. Some aspects of climatic change in the High Arctic during the Holocene as deduced from ice cores. In: Quaternary Paleoclimate. Edited by: W.C. Mahaney. Geo Abstracts, Norwich. pp. 249-271.

Time series of climate-related variables obtained from Greenland and Arctic Canada are presented and compared to each other and to other climate-related time series. Oxygen isotope ratios from the Devon Island Ice Cap are shown to provide a detailed proxy temperature record of a 2-3°C cooling over the last 5000 years. They also contain variations in anti-phase with ^{14}C production rates, thus lending some support to the solar-constant theory of climate change. Insoluble micro-particle concentrations and acidity of the Devon ice core samples are nearly constant over the last 5000 years, suggesting that atmospheric turbidity and volcanic activity have not been the primary controlling mechanisms in the cooling since the climatic optimum 5000 years ago. There is a significant trend of decreasing ionic content of the ice, which is explainable in terms of decreasing availability of marine-derived salts and sulphates and/or decreasing cloudiness over the 5000 years of record.

The data representing the last 500 years are examined in detail and both the δ (^{18}O), and the varying amounts of ice layering, attest to the unique coldness of the Little Ice Age some 200 years ago, and the equally unique warmth of the first half of the present century. A preliminary study of acid layers, δ (^{18}O), and melt layers in the cores, lead the authors to conclude that it is dangerous to assume that volcanic activity has caused major temperature fluctuations in ths 500-year interval.

A.A.

287. FITZHUGH, W. 1977. Population movement and culture change on the central Labrador coast. Annals of the New York Academy of Sciences 288:481-497.

For the purpose of this paper three conclusions are of special interest: (1) seven major cultural changes have occurred within the past 7,000 years; (2) each change exhibits characteristics indicating the arrival of a new population, rather than development from existing traditions; (3) each is also an ethnic shift either from Indian to Eskimo or vice versa.

The most important independent variable in northern ecology is climate. Its influence on animal and human distributions and population sizes is relatively well understood and might help explain the observed culture history pattern.

As can be seen, there is a remarkably close correlation of culture-historical events--specifically, population movements--on the central Labrador coast with major climate shifts in the North American Arctic and Subarctic: (1) Maritime Archaic Indians moved north along the Labrador coast during the period of northward forest expansion in the Hypsithermal. In northern regions they may actually precede the forest, first occupying the central and north coast during the alder-birch thicket vegetation period, a fact that may help explain their maritime specialization. (2) Maritime Archaic retreat coincides with Pre-Dorset Eskimo advance south into the central coast. Evidence of a cooling trend is not found in pollen diagrams but is seen in ice core data. (3) Brinex-Charles Intermediate Indian groups move north at least to the Okak region by 3,400 BP during an ice-core warm period, but glacier advances and pollen diagrams suggest this is a cooling period. (4) Groswater Dorset culture moves south at the beginning of a cool period, which intensifies by 2,500 BP, when (5) Early Middle Dorset people advance south, replacing Groswater Dorset on the central coast. (6) Point Revenge Indians move north in an intensifying warm period ca. 1,000 BP, replacing Dorset Eskimos at least as far north as Okak. (7) Labrador Inuit (Eskimo) replace Indians on all of the central Labrador coast about 400 years ago, at the onset of the Little Ice Age.

This paper demonstrates that climatic change and associated environmental shifts along the forest-tundra boundary in central Labrador may have influenced cultural events repeatedly. The coincidence of most ethnic changes and population movements with recognized climatic shifts strongly suggests causal relationships, filtered, as expected, through social and economic processes. The repeated shifts in ethnic boundaries conform closely to the proposed model of culture change based on traditional Eskimo and Indian adaptations to shifts in forest and Arctic marine environments. It suggests that habitat expansion rather than new cultural adaptation was the mechanism by which these changes occurred. There is also indication that the ethnic tension zone that existed for the last 4,000 years resulted in competition for common resources and affected cultural distributions and movements and rates of change.

Excerpts

288. FLEROW, C.C. 1967. On the origin of the mammalian fauna of Canada. In: The Bering Land Bridge. Edited by: D.M. Hopkins. Stanford University Press, Stanford. pp. 271-280.

We can say confidently that the typical Pleistocene mammals of northeastern Asia were unable to survive the period of the Holocene thermal maximum and the resulting change in the vegetation. The formation of *Sphagnum* associations (muskegs) in northern regions deprived most species of large herbivorous animals (including horses, oxen, and many species of deer and antelope) of their main source of forage. Rhinoceroses and mammoths became extinct at the same time and probably for the same reason. Only the musk-ox and the wood bison survived this crisis in America, persisting in areas where remnants of Pleistocene landscapes were preserved. These "living fossils", once contemporaries of the mammoth, survived to the present time as the last representatives of the Pleistocene fauna.

Excerpts

289. FLETCHER, J.O. 1968. The influence of the Arctic pack ice on climate. In: Causes of Climatic Change. Edited by: J.M. Mitchell, Jr. Meteorological Monographs 8(30):93-99.

An assessment is made of each component of the heat budgets of the surface and of the earth-atmosphere system in the central Arctic, both for an ice-covered ocean and for an ice-free ocean. The annual patterns of atmospheric heat loss for both conditions are obtained as residuals; the relation of these patterns to general atmospheric circulation and glacier accumulation is discussed.

It is shown that atmospheric cooling in the Arctic is closely related to certain indices of atmospheric circulation. An ice-free Arctic Ocean would probably be associated with atmospheric circulation more vigorous in summer at subarctic latitudes and of comparable vigor in winter. The cool summers and warm, moist winters would be highly conducive to glacier growth.

A.A.

290. FLINT, R.F. 1947. Glacial Geology and the Pleistocene Epoch. Wiley and Sons, New York. 589 pp.

A portion of the book is devoted to climate and its fluctuations. Conditions in Canada during glacials and interglacials are described. Postglacial fluctuations are described in greater detail, using evidence from lakes, invertebrates, botany, sea floor, etc. Various hypotheses to explain climatic change are reviewed. Changes in the distribution of plants and animals in concordance with climatic variations are presented.

L.G.

291. FLINT, R.F. 1952. The ice age in the North American Arctic. Arctic 5(3):135-152.

Contains remarks on the glacial and interglacial ages together constituting the Pleistocene epoch inaccurately termed the "ice age". Then follow sections on evidence of glaciation; distribution and types of former glaciers; growth and disappearance of glaciers; evidence of repeated glacial ages; glacial lakes; the postglacial sea and rise of the land; chronology and causes of glaciation; glaciation and life.

A.B.

292. FLINT, R.F. 1976. Physical evidence of Quaternary climatic change. Quaternary Research 6(4):519-528.

Changes of climate have characterized parts, and at times apparently all, of Earth's surface. Changes that have occurred during the Quaternary period have special significance because, being comparatively recent, they are revealed by physical geologic features that are still at or near the surface, as yet little damaged by erosion. Although some of these features can be interpreted in terms that are broadly quantitative, most are still only qualitative in that they are limited to specifying climatic parameters that are positive or negative relative to those prevailing today in the same area. The common parameters indicated by the physical evidence include temperature (mean annual or summer) and precipitation (mean annual or seasonal). More rarely directions and minimum speeds of effective winds can be specified. A useful basis for recontructions of former climates is a check list of the relict geologic features from which climatic inferences can be drawn. Such a list includes: (1) former presence of glaciers: features of glacial erosion, sediments deposited by glaciers, structures created by glacial pushing and dragging; (2) former presence of floating ice: scorings; ice-rafted sediments; ice-rafted clasts in alluvium; (3) displacement of the regional snowline; (4) latitude limits reached by former ice sheets; (5) fluctuation of isotopic paleotemperatures; (6) eustatic fluctuation of sea level; (7) relict features created by frost action; frost-wedged rubble; colluvium deposited by gelifluction and frost creep; frost cracks, ice-wedge casts, and patterned ground; (8) relict eolian features: wind-blown sediments, deflation basins; (9) pluvial features; (10) fluvial features; (11) relict soils; color of sediments; (12) stratigraphy of caverns; (13) temperature and precipitation.

A.A.

293. FORD, D.C., R.S. HARMON, H.P. SCHWARCZ, T.M. WIGLEY, and P. THOMPSON. 1976. Geohydrologic and thermometric observations in the vicinity of the Columbia Icefield, Alberta and British Columbia, Canada. Journal of Glaciology 16(74):219-229.

The Columbia Icefield rests upon limestones containing natural caves that drain waters from the glacier sole. The principal cave is sealed at one end by an extrusion of glacier ice 300 m below the icefield surface. The hydrologic regime of the cave indicates that the modern icefield is temperate in character and that water is present at the glacier sole throughout the year. An interpretation of the air temperature pattern in the cave suggests that the geothermal flux to the glacier is only 10-40% of the expected value because heat is abstracted by melt water circulating through the rock. U, Th and O isotopic analyses of calcite speleothems further indicate that the base of the icefield has probably been during the Classical Wisconsinan - main Würm period. The inundation implies maintenance of a permanent water table at some hundreds of meters above the base in a valley glacier 750-800 m in depth.

Specimen 73 010 displays equilibrium fractionation. It is considered that the $\delta\ ^{18}O$ variation probably represents a variation of temperature of approximately 5 deg, that is 2 deg warmer to 3 deg cooler than the present value of +3.5°C at the site. An increase of 2 deg in the mean annual external air temperature would not suffice alone to destroy the Columbia Icefield.

Probably this persisted at approximately its modern dimensions during the period 155-93 ka. Three warm peaks and one cold trough occur in the 73 010 record. The peaks correlate well with $\delta\ ^{18}O$ peaks that we have measured in specimens which grew at the same time in caves in Bermuda and Kentucky. There is also good agreement with the two older of the three raised coral reefs in Barbados taken to represent climatic optima during the Last Interglacial (Broecker & van Donk, 1970). This suggests that the deep cave speleothems of Castleguard Cave (and therefore the hydrogeothermal state there at a given time) record climatic events of greater than continental scale.

A.A.$^{+}$

294. FORD, D.C., and H.P. SCHWARCZ. 1977. Radiometric age studies of speleothem. Geological Survey of Canada Paper 77-1C:49-51.

The dating and stable isotopic analysis of speleothem has been continued to extend our record of temperature and glacial activity in Canada during the past 350 000 years. Recent work on this project was focused on Vancouver Island where an extensive series of caves was sampled for speleothem. Paleomagnetic studies of speleothem from Vancouver Island and the Rocky Mountains have been initiated. Both $^{230}Th/^{234}U$ and $^{231}Pa/^{235}U$ dating are being applied to speleothem samples through alpha-particle spectrometry. Analyses of stable isotope profiles were made from the Vancouver Island suite of samples. Fluid inclusion studies of speleothem have begun using the direct analysis of $^{18}O/^{16}O$ ratios through fluorination of water liberated by crushing of speleothem. An attempt is being made to improve the uranium series dating of molluscs, through beneficiation of the molluscan tests.

In co-operation with Dr. R.S. Harmon, a synthesis of dates on speleothems formed in caves along the western North American Cordillera over the past 350 000 years has been completed. Periods of intense glaciation are recognizable by the absence of appreciable deposition of travertine and hiatuses in the growth of individual speleothems. These interruptions presumably are due to freezing of water sources and to lowering of biotic activity in the overlying soil. From this synthesis periods of cool climate can be recognized at the following intervals: (Ka = 1000 years BP) 345-320 Ka, 275-240 Ka, 180-155 Ka, and 90-20 Ka. The intensity of the warm intervals, as inferred from the aggregate frequency of speleothem growth during the interval, appears to have decreased from 350 000 years BP to the present.

Excerpts

295. FOSCOLOS, A.E., N.W. RUTTER, and O.L. HUGHES. 1977. The use of pedological studies in interpreting the Quaternary history of central Yukon Territory. Geological Survey of Canada Bulletin 27:1-48.

Soils and paleosols were investigated from pre-Reid (early Pleistocene), Reid (Illinoian or early Wisconsinan) and McConnell (classical Wisconsinan) surfaces in central Yukon. Paleosols on the pre-Reid surface indicate that it was subjected to two distinct climates, an initial one which was warm and subhumid with grassland-shrub vegetation and later a more temperate and humid climate characterized by the development of a Luvisol with a red, textural B horizon, in places over 190 cm (75 in) thick. Subsequently, the climate became colder, resulting in the Reid glaciation. Thermal contraction cracks developed in the pre-Reid deposits beyond the limit of Reid glaciation and were filled with eolian sand, as well as minor silt and clay, to form sand wedges. During the subsequent Reid-McConnell interglacial, a cool, subhumid climate prevailed as evidenced by the Brunisolic characteristics of paleosols on deposits of Reid age. This was followed by a cold period which climaxed with the advent of the McConnell glaciation. Sand wedges also formed in the deposits of the Reid glaciation; the wedges are shallower and narrower than those on the pre-Reid surface, suggesting a shorter cold period. During retreatal stages of the McConnell glaciation, a thin blanket of loess was deposited over McConnell, Reid and pre-Reid surfaces, covering the soils on the Reid and pre-Reid surfaces during postglacial (Holocene) time. Finally, Brunisolic soils developed on the loess blanket and, locally, where the loess is very thin or lacking, on deposits of McConnell age.

A.A.

296. FRENZEL, B. 1966. Climatic change in the Atlantic/sub-Boreal transition in the Northern Hemisphere: botanical evidence. In: World Climate from 8000 to 0 B.C. Edited by: J.S. Sawyer. Royal Meteorological Society, London. pp. 99-123.

Summarizes various theories of climatic changes in Europe and North America during this period. One chart correlates six Alaskan studies with twelve others in North America, another uses data from Kamchatka. Evidence indicates that the beginning of the sub-Atlantic climatic deterioration began 2000-1500 BC in Yakutia and northern Siberia but much later elsewhere in Eurasia. A valuable bibliography of palynological references is included.

A.B.

297. FRENZEL, B. 1973. Climatic Fluctuations of the Ice Age. (Translated by A.E.M. Nairn). Case Western Reserve University Press, Cleveland. 306 pp.

A text book on climatic changes. Relevant sections include methods of investigating ancient climates; principal climatic fluctuations and changes of the Ice Age; and climatic fluctuations during the last cold period in the Northern Hemisphere.

L.G.

298. FRENZEL, B. 1975. The distribution pattern of Holocene climatic change in the Northern Hemisphere. In: Long-term Climatic Fluctuations. World Meteorological Organization, Geneva WMO-421. pp. 105-118.

The factors to be taken into consideration before evaluating past climate are briefly considered, followed by a discussion of the difficulties in finding out the times when climate changed definitely.

G.A.

299. FREY, D.G. 1975. Interpretation of Quaternary paleoecology from Cladocera and midges, and prognosis regarding useability of other organisms. Quaternary Non-marine Paleoecology Conference, University of Waterloo, Waterloo. Program and Abstracts.

The offshore sediments of a lake represent an integration by species of the Cladocera. Actual abundance of littoral species increases toward shore, whereas planktonic species exhibit a peak abundance in the region of the metalimnion. Changes in the ratio of planktonic to littoral species has been used to infer fluctuations in water level. Changes in species composition, including species substitution, allow interpretations about natural eutrophication, development of marshes peripherally during the filling-in process, and marked changes in climate in non-glaciated regions. Shifts in size distribution of species or among species are possibly the result of immigration of planktivorous fishes. Approximation of chydorid distribution by species to the MacArthur broken-stick model indicates stability and balance within the aquatic ecosystem. Departures from this predicted distribution, representing perturbations in the system, have been shown to be associated with change in climate, volcanism, and major activities of man. Community composition is related to lake type, as shown by multivariate analysis. Because the remains of the Cladocera can be identified precisely to species, they can be used for working out present and past distributions and inferring morphological and ecological stability.

Remains of midges (Chironomidae and Chaoborinae) likewise show a peak abundance in the general region of the metalimnion, resulting from the offshore transport of littoral species, but, except in response to marked and rapid changes in water level, relatively few remains of littoral species become incorporated into hypolimnetic sediments. Hence, the species recovered from these sediments provide good indication of changes in oxygen content accompanying eutrophication, or oligotrophication. Initial successional changes in ultra-oligotrophic lakes are possibly controlled more by the food levels in the sediments than changes in oxygen content of the overlying water. Some recent studies are remarkably detailed and incisive in their interpretation.

Some other groups of invertebrates (aside from Coleoptera, molluscs, and ostracods reported elsewhere in this symposium) that are well represented in lake and bog sediments seem to have a high information content but, except for bog rhizopods, are still relatively unexploited scientifically. These include the rhizopods, sponges, neorhabdocoeles, rotifers, bryozoans, copepods, and mites. The species of bog rhizopods show definite relationships to past fluctuations in water content, hence regional climate, with the tyrofoxene species being associated with recurrence surfaces.

Interpretation of the past requires an integration of evidence not only from the morphological remains of various groups of plants (including algae, especially diatoms) and animals but also sedimentary chemistry, mineralogy, and the fabric or structure of the sediments.

A.A.

300. FRITTS, H.C. 1971. Dendroclimatology and dendroecology. Quaternary Research 1(4):419-449.

Dendrochronology is the science of dating annual growth layers (rings) in woody plants. Two related subdisciplines are dendroclimatology and dendroecology. The former uses the information in dated rings to study problems of present and past climates, while the latter deals with changes in the local environment rather than regional climate.

Successful applications of dendroclimatology and dendroecology depend upon careful stratification. Ring-width samples are selected from trees on limiting sites, where widths of growth layers vary greatly from one year to the next (sensitivity) and autocorrelation of the widths is not high. Rings also must be cross-dated and sufficiently replicated to provide precise dating. This selection and dating assures that the climatic information common to all trees, which is analogous to the "signal", is large and properly placed in time. The random error or non-climatic variations in growth, among trees, is analogous to "noise" and is reduced when ring-width indices are averaged for many trees.

Some basic facts about the growth are presented along with a discussion of important physiological processes operating throughout the roots, stems, and leaves. Certain gradients associated with tree height, cambial age, and physiological activity control the size of the growth layers as they vary throughout the tree. These biological gradients interact with environmental variables and complicate the task of modeling the relationships linking growth with environment.

Biological models are described for the relationships between variations in ring widths from conifers on arid sites, and variations in temperature and precipitation. These climatic factors may influence the tree at any time in the year. Conditions preceding the growing season sometimes have a greater influence on ring width than conditions during the growing season, and the relative effects of these factors on growth vary with latitude, altitude, and differences in factors of the site. The effects of some climatic factors on growth are negligible during certain times of the year, but important at other times. Climatic factors are sometimes directly related to growth and at other times are inversely related to growth. Statistical methods are described for ascertaining these differences in the climatic response of trees from different sites.

A practical example is given of a tree-ring study and the mechanics are described for stratification and selection of tree-ring materials, for laboratory preparation, for cross-dating, and for computer processing. Several methods for calibration of the ring-width data with climatic variation are described. The most recent is multivariate analysis, which allows simultaneous calibration of a variety of tree-ring data representing different sites with a number of variables of climate.

Several examples of applications of tree-ring analysis to problems of environment and climate are described. One is a specification from tree rings of anomalies in atmosphere circulation for a portion of the Northern Hemisphere since 1700 A.D. Another example treats and specifies past conditions in terms of conditional probabilities. Other methods of comparing present climate with past climate are described along with new developments in reconstructing past hydrologic conditions from tree rings.

Tree-ring studies will be applied in the future to problems of temperate and mesic environments, and to problems of physiological, genetic, and anatomical variations within and among trees. New developments in the use of X-ray techniques will facilitate the measurement and study of cell size and cell density. Tree rings are an important source of information on productivity and dry-matter accumulation at various sites. Some tree-ring studies will deal with environmental pollution. Statistical developments will improve estimation of certain past anomalies in weather factors and the reconstruction of atmosphere circulation associated with climate variability and change. Such information should improve chances for measuring and assessing the possibility of inadvertent modification of climate by man.

A.A.

301. **FRITTS, H.C. 1976. Tree Rings and Climate. Academic Press, London and New York.** 568 pp.

The history and method of tree ring dating and cross-dating is reviewed. By the application of statistics to tree ring and climatic data, a response or transfer function is derived, relating monthly precipitation and temperature to growth at a given site. Using multivariate statistics, an assembly of sites with differing response functions can be calibrated against known climatic conditions over a given period. By substituting tree ring data from an earlier period of the assembly into the model, estimates can be made of climatic conditions in this period. The climate reconstructions can be verified by independent tree ring data, and by journals, historical data and other forms of proxy data.

G.A.

302. **FRITTS, H.C. 1981. Regionally averaged climatic variation over North America reconstructed by tree-ring analysis. First Conference on Climatic Variations of the American Meteorological Society, January 19-23, San Diego. Abstracts. p. 24.**

Spatial arrays of seasonal temperature, precipitation, and pressure anomalies over North America and the North Pacific for 1901-62 are calibrated with spatial arrays of tree-ring width anomalies from western North America via their principal components. The resulting transfer functions are applied to principal components of past tree growth to obtain estimates of the principal components of climate, which are then transformed into real world estimates of past climate. All estimates are verified against independent climatic data, and the means of two or three estimates for each season are pooled to obtain verified annual averages, regionally averaged values, and time series which were analyzed for the variance spectra. Samples of the most interesting variations are shown; interrelationships between temperature, precipitation, and pressure are described; and some of their applications to problems of climatic variation are discussed.

A.A.

303. FRITTS, H.C., T.J. BLASING, E. DeWITT, G.R. LOFGREN, and K.B. McDOUGALL. 1976. Reconstruction of past climatic variability. Final Report, University of Arizona, Laboratory of Tree-Ring Research, Tucson. 71 pp.

The following are among the achievements made during the first 3 years of a 5-year project to reconstruct past climatic fluctuations in the northern hemisphere from variations in the growth rings of trees: 1) growing international collaboration stimulated by this research effort; 2) development of 127 high quality tree ring chronologies from North America and Europe; 3) the establishment of the international tree ring data bank; 4) evaluation of multivariate techniques for calibration and analysis; and 5) the selection of a revised data set for reconstructing North American climate.

G.A.

304. FRITTS, H.C., G.R. LOFGREN, and G.A. GORDON. 1979. Reconstructing seasonal to centenary variations in climate from tree-ring evidence. International Conference on Climate and History, University of East Anglia, Norwich, July 8-14, Review Papers. pp. 29-58.

Ring-width variation from conifers in arid North America provide information on short time-scale variations in paleoclimate. Dendroclimatic data are especially useful because: 1) they can be dated to the exact year, 2) they can resolve seasonal fluctuations in climate, 3) the climatic signal can be separated from nonclimatic noise, and 4) the data are available from a variety of climatic regimes throughout the world. Dendroclimatic reconstructions are obtained by calibrating 65 tree-ring chronologies from western North America with spatial variations in seasonal temperature, precipitation, or sea level pressure for North America and the North Pacific. Spatial variations in the tree-ring record are transformed into statistical estimates of variations in the seasonal meteorological variables from 1600-1962. The synoptic-scale climatic anomalies that are detected may last from one season to several centuries. Verification of the reconstructions is accomplished using independent meteorological data, historical information, or proxy data. The well-dated, spatially continuous seasonal maps of climate derived from tree rings allow the association of isolated historical facts with meaningful synoptic-scale climatic patterns. The dendroclimatic reconstructions along with historical and other proxy data can serve as a reliable record bridging the gap between the modern meteorological record and the long-term record of traditional paleoclimatology.

A.A.

305. FRITTS, H.C., G.R. LOFGREN, and G.A. GORDON. 1979. Variations in climate since 1602 as reconstructed from tree rings. Quaternary Research 12(1):18-46.

Spatial anomalies of tree-ring chronologies can provide information on high-frequency spatial anomalies in paleoclimate representing droughts, colder-than-normal intervals, and other synoptic-scale features. Examples are presented in which 65 tree-ring chronologies are calibrated with spatial anomalies in North American meteorological records of seasonal temperature and precipitation, and with sea-level pressure over the North American and North Pacific sectors. Multivariate transfer functions are obtained that scale and convert the past spatial variations in the tree-ring record into estimates of past variations in the meteorological record. Objective verifications of the reconstructions are obtained using independent meteorological observations for time periods other than those used in the calibration. Historical information or other proxy data from the 19th century are also used for verifying the decadal (or longer) and regional reconstructions and for identifying strengths and weaknesses of the various sources of information. The reconstructed winter and summer temperatures for the United States and southwestern Canada and winter precipitation for the Columbia Basin and California during the 17th through 19th centuries were found to differ from the 20th century means with large-scale variations evident. Extreme winters similar to 1976-77 are also identified and found to be more frequent in the past, especially in the 17th century. The climatic reconstructions in this time domain are dominated by high-frequency-synoptic-scale fluctuations that can be interpreted as cyclonic-scale changes in atmospheric circulation. Such reconstructions may be useful for testing various climatic models and estimates developed primarily from 20th-century meteorological data against the longer estimated record for the 17th through 19th centuries.

A.A.

306. FRITZ, P., and T.W. ANDERSON. 1975. Paleoclimates and Lake Erie: a study using ^{18}O and ^{13}C in Mollusca and Ostracoda shells. Quaternary Non-marine Paleoecology Conference, University of Waterloo, Waterloo. Program and Abstracts.

The oxygen and carbon isotopic compositions of Mollusca and Ostracoda shells from sediments of Lake Erie (core #13194) can be correlated with major climatic and hydrodynamic events.

The lowest ^{18}O contents ($\delta^{18}O$ = -10 to $-12^{0}/_{00}$ PDB) were found in shells formed some 13,000 to 15,000 years ago in a glacial lake preceeding Early Lake Erie. This lake had initially little or no aquatic vegetation and the dissolved inorganic carbon had a $\delta^{13}C \sim 0^{0}/_{00}$ PDB. The ^{13}C contents decrease with increasing vegetation and reach their lowest levels about 12,700 years ago. At this time we observe also a rise of about $4^{0}/_{00}$ in ^{18}O in the lake which points towards a major climatic improvement at the time of the spruce advance in the drainage basin. Our records are then missing until about 15,000 yr BP at which time both ^{18}O and ^{13}C are still identical to what they were 12,700 years ago - which does not imply constant climatic conditions during this interval. Between about 10,000 and 8,000 a second rise in ^{18}O occurs and $\delta^{18}O$ values as high as $-2^{0}/_{00}$ are now recorded corresponding with the onset of pine. This coincides with a rise in ^{13}C to about $-4^{0}/_{00}$ which indicates that the climatic improvement was paralleled by a deepening of Lake Erie and thus a decrease in the relative importance of aquatic vegetation. During subsequent millennia the ^{18}O slowly decreases with only two clearly visible breaks; one at about 6,000 yr BP and the other in the very recent history. At both times the ^{18}O contents decreased by 1 to $2^{0}/_{00}$ and are probably related to changes in the hydro-dynamic regime of Lake Erie. The ^{13}C contents increase slowly and reach again values close to $0^{0}/_{00}$ n the benthos samples. However, man's activities and the input of increased amounts of isotopically light carbon into the lake has caused a decrease in $\delta^{13}C$ in modern samples by as much as $7^{0}/_{00}$ from the value observed in the benthos.

A.A.

307. FRITZ, P., T.W. ANDERSON, and C.F.M. LEWIS. 1975. Late-Quaternary climatic trends and history of Lake Erie from stable isotope studies. Science 190(4211):267-269.

Oxygen and carbon isotope measurements on mollusk and carbonate shells separated from a long sediment core in central Lake Erie document climatic changes of the Great Lakes region and the evolution of Lake Erie since deglaciation. On the basis of ^{18}O data, two major climatic improvements are recognized, one occurring between 13,000 and 12,000 years before the present (B.P.) and the other between 10,000 and 8,000 years B.P. Changing drainage patterns are also reflected in the ^{18}O contents of the Lake Erie water. Carbon isotopes reflect changes in aquatic vegetation and water depth. The settlement and industrialization of the lake Erie drainage basin is documented in the ^{13}C and ^{18}O contents of modern mollusks.

A.A.

308. FULTON, R.J. 1971. Radiocarbon geochronology of southern British Columbia. Geological Survey of Canada Paper 71-37:1-28.

The radiocarbon-dated Quaternary history of southern British Columbia extends over the past 52,000 years. This interval has been subdivided into 3 major geologic-climate units: Olympia Interglaciation, Fraser Glaciation, and Postglacial.

In southern British Columbia the Olympia Interglaciation began more than 52,000 years ago and ended about 19,000 years BP. Meagre information available from the west coast suggests that the climate during this period was cool and damp but probably not too different from present. *Bison* and *Equus* bones collected from deposits of this age in the interior of British Columbia indicate that the climate was such that it could support large herbivorous animals. The Olympia Interglaciation sedimentary framework, the processes active and the deposits formed, were similar to those of the same area at present. Three major depositional cycles have been recognized: (1) an early period of deposition at base levels higher than present, (2) a period of low base levels, and (3) a late episode of deposition at base levels above those of present day.

Fraser Glaciation ice did not occupy the lowlands of southern British Columbia until later than 19,000 years ago, but probably began to build-up in the mountainous areas before that time. Parts of the west coast were ice-free about 13,000 years ago and all of southern British Columbia was probably as free of ice as at present by 10,000 years BP.

From the time of deglaciation to about 8,000 years ago, isostatic movements tended to control local sea level and to mask eustatic changes. The apparent sea levels were high, due to isostatic depression at the time of Fraser deglaciation. Isostatic adjustments caused local sea levels to fall during deglaciation, rise again about 11,000 years ago and fall below the present level about 8,000 years BP. At that time, it appears that approximate isostatic equilibrium was achieved and the later sea level history is largely one of changes in response to worldwide eustatic fluctuations.

The Postglacial record of southern British Columbia includes four dated ash falls: (1) Mazama, about 6,600 year BP; (2) St. Helens Y, about 3,300 years BP; (3) Bridge River, about 2,400 years BP, and (4) St. Helens W. (?), later than 1,200 years BP. The climate was cold 12,000 years ago, but it warmed sufficiently to be similar to the present when most of southern British Columbia was deglaciated. A thermal maximum about 6,000 years ago was followed by a cooler period which persisted until present. Glacial advances took place 3,000 to 2,500 years ago and in the past few centuries. During this most recent advance, the alpine glaciers of southern British Columbia were more extensive than at any time since the end of Fraser Glaciation about 10,000 years ago.

A.A.

309. FULTON, R.J., and G.W. SMITH. 1978. Late Pleistocene stratigraphy of south-central British Columbia. Canadian Journal of Earth Sciences 15(6):971-980.

The late Pleistocene deposits of south-central British Columbia record two major glacial and two major nonglacial periods of deposition. The oldest recognized Pleistocene deposits, called Westwold Sediments, were deposited during a nonglacial interval more than 60000 years ago. Little information is available on the climate of this period, but permafrost may have been present at one time during final stages of deposition of Westwold Sediments. The latter part of this nonglacial period is probably correlative with the early Wisconsin Substage of the Great Lakes-St. Lawrence Valley area. However, deposition of the Westwold Sediments may have begun during the Sangamon Interglacial.

Okanagan Centre Drift is the name applied to sediments deposited during the glaciation that followed deposition of Westwold Sediments. Okanagan Centre Drift is known to be older than 43800 years BP and probably is older than 51000. It is considered to correlate with an early Wisconsin glacial period.

Bessette Sediments were deposited during the last major nonglacial period, which in south-central British Columbia persisted from at least 43800 years BP (possibly more than 51000) to about 19000 years BP. This episode corresponds to Olympia Interglaciation of the Pacific Coast region and the mid-Wisconsin Substage of the Great Lakes - St. Lawrence Valley area. During parts of Olympia Interglaciation the climate was probably as warm as the present-day climate in the interior of British Columbia. Information from coastal regions indicates that there may have been periods of cooler and moister climate.

Kamloops Lake Drift was deposited during the last major glaciaton of south-central British Columbia. Ice occupied lowland areas from approximately 19000 to 10000 years BP. This period corresponds approximately to the Fraser Glaciation of the Pacific Coast region and the late Wisconsin Substage of central and eastern parts of North America.

A.A.

310. FYLES, J.G. 1963. Surficial geology of Horne Lake and Parksville map-areas, Vancouver Island, British Columbia. Geological Survey of Canada Memoir 318:1-142.

This report is concerned with part of the eastern coastal lowland of Vancouver Island, the first range of mountains and the intermontane Alberni Valley. Thick surficial deposits on the coastal lowland record two glaciations separated by a major interstadial interval. The principal surficial deposits are, from oldest to youngest: Mapleguard sediments, Dashwood drift, Quadra sediments, Vashon drift, Capilano sediments (early post-glacial), and Salish sediments (modern).

The Mapleguard sediments are unfossiliferous clays, silts, and sands. The Dashwood drift consists of a till-sheet complex deposited during an 'old' regional glaciation. The Quadra sediments comprise a lower marine (and glaciomarine) clay unit, a middle plant-bearing silt-gravel unit, and a thick upper fluvial sand unit. The Quadra records a major cool interstadial interval and has yielded radiocarbon ages ranging from 25,000 to more than 40,000 years.

Varied glacial deposits comprising the Vashon drift relate to a single glacial invasion equivalent to the 'classical' Wisconsin. An ice-sheet complex covered the entire region, except for a few high peaks, at the glacial climax, and then separated into a network of glaciers and glacial remnants during deglaciation. Retreating glacial lobes in the Georgia depression and Alberni Valley were bordered by the sea.

Since retreat of the glacier, marine, fluvial, lacustrine, swamp, and colluvial deposits have accumulated. Deglaciation was followed by a cool interval during which the land rose relative to the sea by 500 feet in the coastal lowland and 300 feet in Alberni Valley. Organic materials formed during the later half of this uplift have radiocarbon ages of 11,500 to 12,350 years. The last several thousand years (possibly 5,000 or more) have been characterized by a climate like the present and a sea-level that was within a few feet of the present.

A.A.

311. GAGNON, R., et S. PAYETTE. 1981. Fluctuations Holocènes de la limite des forêts de mélèzes, Rivière aux Feuilles, Nouveau-Québec: une analyse macrofossile en milieu tourbeux. Géographie physique et Quaternaire 35(1):57-72.

The aim of this project was to outline the fluctuations of the limit of tamarack forests during the Holocene, based on wood macrofossil evidence collected in organic deposits at Rivière aux Feuilles, Nouveau-Québec (ca. 58°15'N, 72°W). The history of postglacial forest-line is based on an exhaustive collection of more than 700 macrofossils, from which a sampling of 67 macrofossils were radiocarbon dated. Results indicate that the tamarack was present in the area in 4500 years BP. Since then the tamarack transgressed, at least twice, the position of the modern forest-lines: 1) between 3500 and 2700 years BP, when the maximum forest-line expansion towards the north took place; and 2) between 2000 and 1600 years BP, when a less extensive northward displacement was registered. Very few macrofossils dated around 2650-2400, 2100-2000, 1600-1300 years BP were collected. This is interpreted as a regression of tree populations during these periods. After 1300 years BP no forest-line displacement was registered; however, there were local expansions of tamarack populations between 1000 and 600 years BP, and regressions between 550 and 250 years BP. In spite of an intensive search in organic deposits, no tamarack macrofossil was collected further north than 5 km of the modern forest-line.

A.A.

312. GASCOYNE, M., D.C. FORD, and H.P. SCHWARCZ. 1981. Late Pleistocene chronology and paleoclimate of Vancouver Island determined from cave deposits. Canadian Journal of Earth Sciences 18(11):1643-1652.

Several speleothems from Cascade Cave near Port Alberni, Vancouver Island, have been dated by the ^{230}Th/^{234}U method. The greater abundance of speleothems formed during the period 65,000-45,000 BP suggests that this was the warmest part of the Olympia interstadial. Using modern cave temperature and the variation of δ ^{18}O of seawater over the dated period, the profiles of δ ^{18}O are interpreted in terms of a paleotemperature record for the Olympia interstadial in Vancouver Island. Results shows a gradual cooling from 4°C at 64,000 BP, to 0°C between 35,000 and 28,000 BP. Growth ceased at 28,000 BP, possibly due to the persistence of freezing conditions. These results are consistent with conditions necessary for speleothem growth and with published work on surficial Wisconsin deposits in the area. No distinct, short warming or cooling events are seen in the record, probably due to thermal buffering by the adjacent ocean.

C.R.H.

313. GASCOYNE, M., H.P. SCHWARCZ, and D.C. FORD. 1980. A paleotemperature record for the mid-Wisconsin in Vancouver Island. Nature 285(5765):474-476.

Calcite speleothems are deposits of calcium carbonate (stalagmites and flowstones) found in limestone caves. They are formed by precipitation from groundwater supersaturated in Ca^{2+} and HCO$_3^-$. Their oxygen isotopic composition is controlled by the isotopic composition of the seepage waters from which they are deposited and by the temperature of formation. We report here the discovery of mid-Wisconsin speleothems from a cave in Vancouver Island which are significantly depleted in ^{18}O relative to modern calcite in the same cave. We interpret the variations in ^{18}O content over this period as an absolute palaeotemperature record for the area.

These data show a gradual cooling at this site between 65 and 30 kyr BP at an almost constant rate, comparable with the uniform rate of continental ice accumulation suggested by Figure 1. The local setting of this cave suggests that its temperature is responding to the average sea-surface temperatures of water masses along the northern Pacific coast and that these in turn were gradually cooling through this interval.

A.A.$^+$

314. GEORGIADES, A.P. 1977. Trends and cycles of temperature in the Prairies. Weather 32(3): 99-101.

At Winnipeg (1875-1973), Regina (1884-1973) and Saskatoon (1902-1973) the annual mean temperature increased up to about 1930. Using two sets of data, up to and including 1931, and 1932 to 1973, and linear trend analysis the slope 'b' is found to be positive up to 1931 but negative after. Power spectrum analysis shows significant peaks for Winnipeg at period 4.16 years and 3.33 years, for Regina at 2.56 and 5.00 years and for Saskatoon at 2.63 and 5.00.

G.A.

315. GIDDINGS, J.L., Jr. 1947. Mackenzie River delta chronology. Tree-ring Bulletin 13(4):26-29.

Comparison of tree growth on the MacKenzie River with weather records from Aklavik shows no strong relation to precipitation with marked agreement to mean July temperature. Temperature of the growing season appears to form the principal control of cross dating quality.

Thomas

316. GIDDINGS, J.L., Jr. 1954. Tree-ring dating in the American Arctic. Tree-ring Bulletin 20(3/4):23-25.

In a survey article the author points out the difficulties in interpreting tree rings in the Arctic and the correlation of this growth with temperature and precipitation. Cross-dating is much more difficult in the Arctic than it is in the south.

Thomas

317. GODMAIRE, A., et S. PAYETTE. 1981. Dynamique spatio-temporelle d'une bande forestière près de la limite des forêts, Rivière aux Feuilles, Nouveau-Québec. Géographie physique et Quaternaire 35(1):73-85.

The spatial distribution of dead or living individuals among larch (*Larix laricina* (Du Roi) K. Koch) and black spruce (*Picea mariana* (Mill.) BSP.) populations within a forest strip has allowed us to reconstruct the forest evolution since 1550 years BP. The influence of climatic conditions and forest fires on these populations could thus be determined. The fluctuation of success in tree species regeneration and that of the spatial distribution of trees which appeared during the last five decades are ascribed to climatic conditions. Two recent fires (100 and 160 years ago) have in part influenced the distribution pattern as well as the success of colonization of older trees. These fires have restricted the tree populations to a damp depression and have affected their structure. The different soil horizons containing charcoal, detected on the site, (1550 ± 130 years BP, 1170 ± 100 years BP, 640 ± 80 years BP) and their spatial distribution indicate that forest fires have had an influence on the extent of the forest cover. Prior to 1550 years BP, the forest strip covered a greater surface than today. After the fire of 1170 years BP, a change in the number and the dynamic of fires, associated with periglacial activity during that period, suggests a cooler climate. Finally, the spatial fluctuations of the tree populations are associated with the climatic changes that have occurred since 1550 years BP and that are brought out by the absence or the success of tree species regeneration since the larch and the black spruce have burnt.

A.A.

318. GODSON, W.L. 1975. Is the earth getting hotter or colder? Canadian Geographical Journal 90(5):42-50.

The author discusses some consequences of world-wide climatic change but the emphasis is on Canada. He presents some of the possible man-made influences on climate, describes Pleistocene trends, and exposes study programs, planned and present, on climate change. He concludes, "... Canada is more weather-sensitive than countries whose economies are not so heavily dependent upon outdoor activity and climate. Our country therefore has the most compelling reasons to accept responsibility and leadership in climatic research and in the application of new knowledge."

L.G.

319. GOLDTHWAIT, R.P. 1966. Evidence from Alaskan glaciers of major climatic changes. In: World Climate from 8000 to 0 B.C. Edited by: J.S. Sawyer. Royal Meteorological Society, London. pp. 40-53.

Studies of glaciers in the Glacier Bay National Monument, Alaska and the Icefield Ranges, Yukon Territory are reviewed, with maps and stratigraphic sections, and the main findings relevant to climatic change are summarized. They appear to establish a unified history of major glacial fluctuation, and indicate a 4400-yr warm period ending approximately 2700 BC, followed by ice expansion 2700-2200 BC and a greater expansion commencing ca. 400 BC and in many cases reaching climax as late as 1890 AD. Some climatic deductions are discussed and a correlation with other Cordilleran glaciers attempted.

A.B.

320. **GORDON, J.E. 1980. Recent climatic trends and local glacier margin fluctuations in West Greenland. Nature 284(5752):157-159.**

Recent climatic trends in the Arctic have been characterized by a general cooling between the mid-1950s and the late-1960s, following by a return to warmer conditions in the early 1970s. Throughout the Canadian Arctic Archipelago and at Thule in north-west Greenland a marked decrease in summer temperature occurred after 1963, and winter precipitation increased. These changes were accompanied by a lowering of the average July freezing level height by as much as 500m, decreased glacier mass loss and increased glaciation. Here I report similar climatic trends in West Greenland and demonstrate different glacier reponses, in particular an advance of cirque and small valley glaciers since about 1968, contrasting with a simultaneous retreat of larger valley and icefield outlet glaciers.

The advance of the cirque and small valley glaciers since about 1968 coincides in its first part with a period of decreased summer temperatures and a trend towards colder, wetter springs and colder, drier autumns, and can be seen as a direct response to this climatic deterioration. However, despite a reversal in all these trends after 1971, the glaciers have continued to advance at least until 1978. Therefore, the observed pattern of glacier margin fluctuations matches only in part the recent temperature trends. The continued advance of the glaciers probably reflects a lag in their response to the increased precipitation during the late 1950s and 1960s. The magnitude of this lag is at least 9 yr judging from the fact that precipitation began to decrease sharply after 1969.

The temporary reactivation interrupting the continued recession of one of the outlet glaciers and the largest valley glacier can be explained as a direct response to the climatic cooling, particularly in summer seasons during the late 1960s and early 1970s. However, these glaciers do not seem to have responded significantly to the increased precipitation in the 1950s and 1960s. This could reflect either a lag or a damping of any effects due to the size of the glaciers. The former is more probable because of the magnitude and duration of the precipitation increase. The continued recession of the two outlet and the largest valley glaciers at present can be explained partly as a direct response to the recent climatic warming and partly as a lag response to the relatively low precipitation during the 1940s and early 1950s. If this is the case, then a minimum lag of 20 to 30 yr in the response of these glaciers to precipitation changes is implied.

A.A.

321. **GRANDTNER, M.M., P.Y. BLANCHETTE, R. COULOMBE, N. TETRAULT, et S. BERNARD. 1977. Végétation, sol et écoclimat actuel des tourbières de la région de Québec. Géographie physique et Quaternaire 31(1-2):135-138.**

The authors present some of the results of recent ecological studies in the following bogs of Québec City area: Les Saules, Champigny, Beauséjour and Harlaka. Their vegetation has been classified in thirteen associations, grouped in four physionomic units. They occupy different types of soils which belong mainly to the organic and gleysolic orders. The ecoclimate of these bogs is significantly different from the general climate; radiation under canopy is lower and soil temperature is lower in summer. The authors suggest some possible utilizations of these results in paleoecology and in management, interpretation and protection of these environments. They propose that the two bogs from Greater Québec be used for ecological interpretation of nature and that the Beauséjour bog, after being enlarged, should be declared an integral ecological preserve.

A.A.

322. GRANT, D.R. 1975. Recent coastal submergence of the Maritime Provinces. In: Environmental Change in the Maritimes. Edited by: J.G. Ogden, III and M.J. Harvey. Proceedings of the Nova Scotia Institute of Science 27 (Supplement 3):83-102.

For more than a century it has been known that the Maritimes are submerging. This report describes the extent, age, sequence, rate and causes of the relative rise of sea level, primarily by determining the radiocarbon and calendar ages of submerged features that originated at or near former high tide, and measuring their depths below present high tide. Variations in the rate of sea-level rise, and a recent acceleration are reflected in stratigraphy of coastal deposits and discontinuities of beach morphology. Evidence of submergence during the last 5000 years is recorded by tree-stumps and other freshwater vegetation overridden by transgressing barrier beaches, and buried beneath tidal marshes. Supplementary evidence for the last 1000 years includes drowned Indian campsites, colonial artifacts buried in tidal mud, and the rise of high tide at the fortress of Louisbourg. Tide-gauge records and geodetic re-levelling confirm that the coast is still submerging today.

Forty-seven age and depth determinations on former lower positions of high-tide datum indicate the region is submerging 30 cm (one foot) per century, whereas average world-wide rate of sea-level rise is only 6 cm/century. Excessive submergence in the Maritimes is believed due to subsidence of the earth's crust as a former glacier-marginal bulge collapses. In the Bay of Fundy an additional factor has been the amplification of tidal range as world-wide rise of sea level widened and deepened the entrance, and optimized basin geometry. Both subsidence and tidal change are indirect consequences of climatic change. Details of past climatic variation, and indications of future change, can be deciphered from the shape and composition of Maritime coastal features.

A.A.

323. GRANT, D.R. 1977. Glacial style and ice limits, the Quaternary stratigraphic record, and changes of land and ocean level in the Atlantic Provinces, Canada. Géographie physique et Quaternaire 31(3-4):247-260.

Evidence from scattered stratigraphic sections, from the relationship of a sequence of ice flow indicators to a raised interglacial marine platform, together with the limits of freshly glaciated terrain against weathered bedrock areas, indicates that late Wisconsinan glaciers spread weakly toward, and in many areas not beyond, the present coast. These were fed by a complex of small ice caps located on broad lowlands and uplands. The limiting factor was the deep submarine channels that transect the region. Thus, Laurentide ice was limited to northern Gulf of St. Lawrence. With this pattern of centripetal flow toward the Gulf, large areas remained unglacierized. There is now better geological corroboration of Fernald's hypothesis of nunatak botanic refugia, though there was, perhaps during early Wisconsinan time, grounded ice in the Gulf and an outlet glacier in Laurentian Channel. Raised postglacial shorelines fit the model, with a general tilt toward the main shield ice sheet, but with two broad domes reflecting the ice complexes over New Brunswick and Newfoundland. Older emerged and submerged shorelines beyond the glacial limit complicate the pattern. At present northern regions are still rebounding while a zone of subsidence is migrating inland from the continental margin.

A.A.

324. GRAY, J., and P. THOMPSON. 1976. Climatic information from $^{18}O/^{16}O$ ratios of cellulose in tree rings. Nature 262(5568):481-482.

The high precision of dendrochronology makes possible the construction of short (~ 9000 yr) detailed records of past climates. This paper explores the possibility of using the oxygen isotopic composition of cellulose from tree rings as a 'thermometer' to measure past temperatures. Using meteorological data from Edmonton we have shown that temperatures can be measured with a precision of ~ ±0.15°C when averaged over a 5-yr period.

G.A.

325. GRAY, J., and P. THOMPSON. 1977. Climatic information from $^{18}O/^{16}O$ analysis of cellulose, lignin and whole wood from tree rings. Nature 270(5639):708-709.

The oxygen isotopic composition of cellulose, whole wood and lignin from tree rings in a white spruce *Picea glauca* which grew in the Edmonton area from 1882 to 1969 have been measured. Using meteorological records we have evaluated the responses of the $^{18}O/^{16}O$ ratios of the three components of the tree rings to seasonal temperatures. Results show a high correlation between cellulose $^{18}O/^{16}O$ ratios and mean annual temperature, a poorer, though still significant correlation between whole wood $^{18}O/^{16}O$ ratios and mean annual temperature and no significant correlation between lignin $^{18}O/^{16}O$ ratios and mean annual temperature.

G.A.

326. GRAYSON, D.K. 1975. A Bibliography of the Literature on North American Climates of the Past 13,000 Years. Garland, New York. 206 pp.

Contains 1398 titles, without annotations. Each entry is indexed according to seven geographical subdivisions of the United States and Canada. There is also a "General" category for those studies dealing with much or all of North America.

L.G.

327. GRAYSON, J.F. 1958. The postglacial history of vegetation and climate in the Labrador -Quebec region as determined by palynology. Dissertation Abstracts 18(4):1229.

Palynological evidence indicates three regional periods. Tundra vegetation dominated during the first period. A *Betula-Alnus* association succeeded the tundra and was dominant during the second period. The boreal woodland succeeded the *Betula-Alnus* association and has been dominant for the past 4000 to 5000 years. Superimposed upon these regional periods, local succession in the vicinity of each station apparently developed in the same order as the regional succession.

As for climatic change, only a continued warming trend, with pulsations, from the time of deglaciation of this region to the present is substantiated.

Much of this region was deglaciated about 8000 years ago and practically all of it about 6000 years ago.

A warm period, which reached its maximum about 3500 years ago, is indicated. It is questionable whether this period was warmer than the present climate of this region.

No evidence was found to support the Final Period Revertance Theory in this region.

pA.A.

328. GRYNIEWSKI, P.N. 1981. Impact of climate on programs of the Ontario Ministry of Natural Resources. In: Climate Change Seminar Proceedings. Regina, March 17-19. Canadian Climate Centre, Downsview. pp. 53-59.

"A number of programs operated by the Ministry are markedly affected by climate, and especially by changes in climate. The cost to the economy of climatic changes can be enormous. Rather than cover the entire spectrum of climate change, this paper deals with the impact of climatic variability on three programs of the Ontario Ministry of Natural Resources, namely, flood mitigation, silviculture and forest fire management."

A.I.

329. GUNNARSSON, G. 1979. Some interdisciplinary problems of climate and history: a study in causal relations and other questions of methodology. International Conference on Climate and History, University of East Anglia, Norwich, July 8-14, Abstracts, pp. 27-28.

For connecting climate history and human history the causal link must be studied carefully. This is usually agriculture and fishing; in other words economically applied biology. The impact of the climate on these basic occupations must be studied scientifically, without any vague suggestions. Usually such a study reveals a far more complex picture than the simple correlation between man and nature usually given.

The decision to apply ecological factors in explaining human history can first be made when all the relevant explanatory factors have been studied. Usually one finds that purely economic factors have at least the same significance in explaining a historical process as ecological factors. It is therefore a good rule to use in the first instance the *endogenous* variables when explaining a human society.

This does not mean that climatic theories (as *exogenous* variables) about human society are useless or dangerous. On the contrary, they often seek to explain something previously not explained and by raising the question they may stimulate research. But more importantly the study of how the challenge of the climate is met by society is essentially a socio-economic one. Some knowledge about the challenge, that is the climate, is a prerequisite for such studies. The synthesis of ecological history and socio-economic history may have a very high explanatory value as regards human history. This we can do best by studying the history of the vulnerability of man to climate. There are indications that this vulnerability has been constantly changing in history, during some periods increasing and other periods decreasing. This type of study obviously excludes all monocausal explanations.

Many concrete examples will be taken from Icelandic economic history before 1800. Iceland has often been considered as one of the marginal areas for human population because of the climate. My conclusion is that socio-economic factors give the best explanations for economic and demographic crises in Iceland, both during the Middle Ages and the Little Ice Age.

Natural scientists should be well aware of the possible political implications of their trade: for example, in explaining a process *only* through the inevitability of nature, when alternative explanations may easily be found.

Historical records may be of great value to the natural scientist in his/her work. But he/she must avoid the use of subjective judgements or indirect evidence (such as fishing or agricultural yields). For instance, records of fish catches tell us little about marine biology but much about technological history.

A.A.

330. GUTHRIE, R.D. 1980. Bison and man in North America. Canadian Journal of Anthropology 1(1):55-73.

Rapid evolutionary changes in bison morphology and the frequent occurrence of bison in archaeological sites make them particularly important in North American Quaternary studies. Major morphological trends in bison evolution are discussed in an update of bison paleogeography, and a conceptual model is proposed to account for the changes in bison evolution. Central to this picture is the steppe bison, *B. priscus*, which dominated the Holarctic throughout the last half of the Pleistocene. It was used as a food item in Eurasia and Beringia but was not the major prey species. In North America, however, bison became the staple meat resource at the end of the last glacial. The increasing density of bison resulted from vegetational change and the extinction of competitor species. Seasonality of available resources was critical in bison adaptations and numbers, which in turn affected the modes of human bison hunting and human density in North America.

A.A.

331. HAAG, W.G. 1962. The Bering Strait land bridge. Scientific American 206(1):112-123.

Presents geological, botanical, and zoological evidence for a broad land bridge between Asia and North America, making possible the large-scale migration of animal and plant life during Tertiary and Pleistocene time. Recent studies indicate that the Bering-Chukchi plain was as much as 1300 mi. wide, was above water throughout most of the Tertiary as well as during maximum glaciation in the Pleistocene. Neither the Chukotsk Peninsula in Siberia nor the Seward Peninsula in Alaska was blocked by ice; much of central Alaska remained ice-free during the ice age. The theory on the causes of glaciation, requiring a warm Arctic Ocean to provide moisture for precipitation over the Hudson Bay area, postulates also conditions favorable for life on the land bridge. Zoological and botanical evidence suggests a wide bridge: the animals that crossed it were not typical cold-climate species, and a bridge 700 mi. wide is believed necessary to account for the present distribution of plants in Alaska and northeastern Siberia.

A.B.

332. HADDEN, K.A. 1975. A pollen diagram from a postglacial peat bog in Hants County, Nova Scotia. Canadian Journal of Botany 53(1):39-47.

The pollen stratigraphy of a 6.7-m section of bog peat from west-central Nova Scotia shows three major pollen zones, viz., the zone of spruce maximum (9180-8505 before present (BP)); the zone of pine and oak maxima (8505-6290 BP); and the upper deciduous zone, which could be more accurately described as the bimodal hemlock zone (6290 BP to present day). The zone of hemlock minimum is dated at 4415 BP. The spruce assemblage denotes a cool, wet climate. The decrease in spruce and increases to maxima of pine and oak are interpreted in terms of higher temperatures and lower precipitation. Further temperature increase, perhaps accompanied by increased precipitation, resulted in the migration of hemlock into the area subsequently suppressed during the period of maximum warmth and dryness. Increased precipitation followed by decreased temperatures led firstly to a second hemlock stage and later to increased coniferous growth. Increased representation of grasses and adventives in the upper levels of the assemblage are indicative of European colonization.

A.A.

333. HAGE, K.D. 1977. Local history as a source of climatic information. In: Applications of Climatology: Proceedings of the Workshop and Annual Meeting sponsored by the Alberta Climatological Committee. Edited by: J.M. Powell. Canadian Forestry Service, Northern Forest Research Centre Edmonton, Alberta, Information Report NOR-X-193:11-28.

Local or community history in its many forms contains numerous observations of the impact of weather and climate on life and property, and of weather events of small time and space scales that are usually lost between official weather stations. Large numbers of local histories have been compiled by community organizations in recent years and these are being used as sources of data for a study of tornadoes in Alberta. Preliminary results, based on a small unverified sample, are shown for southern Alberta (Townships 1-25) and south-central Alberta (Townships 26-50). Special attention is paid to possible temporal and spacial bias exhibited by these data and by the official list of Alberta tornadoes to interpretation problems and to date-time verification problems. Formulas for estimating average lengths and widths of tornado destruction paths from census and local history statistics are presented as examples to illustrate the kinds of parameters and assumptions that will be needed in future quantitative analyses.

G.A.

334. HALSTEAD, E.C. 1968. The Cowichan Ice tongue, Vancouver Island. Canadian Journal of Earth Sciences 5:1409-1415.

The nature of distribution of unconsolidated surficial deposits on southeastern Vancouver Island suggest that glacier ice occupied the Cowichan Valley during a period of the late Pleistocene Epoch that extends from an early alpine phase, Evans Creek Stade, until after the last or Sumas Stade of the Fraser glaciation. The distribution of drift deposits, the Saanichton gravel, and attendant till define, in general, the limits of the Cowichan Ice tongue that later coalesced with ice of the Strait of Georgia. Temporary halting during deglaciation, assumed to be related to the colder temperatures of the Sumas Stade as evidenced on British Columbia's mainland, resulted in the deposition of the Koksilah gravel, a group of ice contact deltas, kame moraines, and kettled kames, which overlie till deposits of the Cowichan Ice tongue and (or) Vashon till.

A.C.

335. HAMELIN, L.E. 1957. Les tourbières réticulées du Québec-Labrador subarctique: interprétation morpho-climatique. Cahiers de géographie de Québec 2(3):87-106.

String-bogs are essentially marshy zones of ponds separated by strips of vegetation, the whole presenting a rectilinear or concentric pattern. They are found in Quebec-Labrador 50°-55°N., are related to an optimum thickness of peat, and occur far south of permafrost limits in regions where snow maintains great depth. Formation of the bogs approx. 4000 B.C.-1600 A.D. is traced briefly; a combination of formative processes is suggested: sub-aquatic solifluction, gathering of isolated vegetation-covered hillocks, tearing of the plant covering by internal balls of ice, shifting of malleable peaty material, differential formation of ice in the ponds, snow action. Similar bogs are found in other parts of Canada, Alaska, Scandinavia and U.S.S.R. A brief review of the literature is given.

A.B.

336. HANSEN, H.P. 1940. Paleoecology of two peat bogs in southwestern British Columbia. American Journal of Botany 27(3):144-149.

Pollen analyses of two peat post-Vashon bogs in southwestern British Columbia show that the pioneer postglacial forests consisted largely of lodgepole pine, suggesting an initial cool and damp period.

This was followed by a spruce-pine forest with a predominance of spruce, indicating an increase in moisture and temperature.

A third period of decreasing moisture and temperature is marked by the increase and dominance of Douglas fir and hemlock, which has existed to the present.

The method of formation of Lulu Island, its physiographic and edaphic instability, its position in relation to winds and adjacent forests, and plant succession on the island and bog are responsible for an inaccurate representation of nearby forests by their pollen as preserved in the peat. The Westminster bog, however, probably records a fairly accurate representation of adjacent forests.

Climatic interpretations are tentative but essentially agree with those of pollen analyses of other bogs in the Pacific Northwest.

A.S.

337. HANSEN, H.P. 1949. Postglacial forests in west central Alberta, Canada. Bulletin of the Torrey Botanical Club 76(4):278-289.

Pollen analysis of four peat sections from bogs lying between Edmonton and the Rockies in west central Alberta, reveal that lodgepole pine and spruce have been the predominant forest tree species in adjacent areas during the time represented by the sedimentary columns. Since these bogs lie west of the border of the Altamont (Late Wisconsin) moraine and on older Keewatin drift, but probably east of the Late Wisconsin Cordilleran ice border, it is possible that they record pre-Late-Wisconsin forests, that had persisted in an ice-free corridor during this glacial stage. This is consistent with Hultén's theory that continental western American radiants from a Beringia center had migrated southward before the Wisconsin glaciations and persisted in ice-free areas close to or within the ice front during at least the Late Wisconsin stage. The postglacial warm, dry interval, evidenced from so many sources, may be slightly recorded by an influx of grasses with some chenopods and composites in the vicinity of the Edson bog, 125 miles west of Edmonton.

A.S.

338. HANSEN, H.P. 1950. Pollen analysis of three bogs on Vancouver Island, Canada. Journal of Ecology 38(2):270-276.

Although the pollen profiles of the three sections reflect the different climates in the three areas, both present and during the post-glacial, there seem to be few or no trends that denote climatic fluctuations. The recorded changes in forest composition probably represent normal forest succession in response to a general amelioration of the climate and modification of the sterile mineral substratum left in the wake of glaciation. These changes were undoubtedly somewhat conditioned by periodic fire and perhaps insect and fungus disease. The warm, dry period which has been dated as between 8000 and 4000 years ago, and is well recorded in pollen profiles from eastern Oregon and Washington and the Willamette Valley in western Oregon, is not in evidence (Hansen, 1947). Although this xerothermic stage is not clearly borne out by pollen profiles of bogs from the Puget Lowland, the consistence of the profiles in showing Douglas fir as attaining its maximum below a volcanic ash level, dated at 6000 years, and the expansion of western hemlock above the ash horizon, suggests a cooler and moister period in more recent time. In the Qualicum Beach section hemlock expands in the upper third, and in the Black Creek section hemlock has been the predominant species during the time represented by the upper two-thirds. The higher proportions of hemlock in the forests in more recent time may reflect slightly increased moisture, but the general increase of this species throughout most of the profiles also suggests development of a soil profile with sufficient humus which is so essential for this species to thrive. The small size of Vancouver Island, the several life zones and prevailing westerly winds have resulted in dilution of the pollen from forests adjacent to the bogs by that from inland forests at higher altitudes. It seems doubtful that the marine climate has fluctuated materially since the early post-glacial amelioration of the proglacial influence.

Excerpt

339. HANSEN, H.P. 1952. Postglacial forests in South Central Alberta, Canada. American Journal of Botany 36(1):54-65.

Pollen analyses of seven peat sections in the vicinity of Edmonton, Alberta, reveal that pine is predominantly represented throughout. The age of the sections is uncertain, but it seems probable that most of them are post-Altamont (Late Wisconsin), while some may be a little older. Unless pine is over-represented, its recorded predominance in the lowest levels is somewhat anomalous as compared with the record of spruce-fir predominance in the earliest postglacial pollen-bearing sediments of the Great Lakes region and New England. Several possible causes of this disparity are suggested. An influx of grasses, chenopods, and composites denotes a warm, dry maximum during the Postglacial, which is further supported by the present extent of the black soil zones showing that grasslands were far more extensive at one time than at present. An abrupt increase of spruce to its maximum in the upper levels suggests a cooler and moister climate in more recent time. Continued spruce expansion to the present apparently was interrupted by fire and cultivation, the first probably more prevalent in the Cordilleran forest to the west where lodgepole pine has recently expanded. Clearing of spruce forests in the vicinity of the bogs may also be responsible for spruce decline in the upper two horizons of most sections.

A.S.

340. HANSEN, H.P. 1952. Postglacial forests in the Grande Prairie-Lesser Slave Lake region of Alberta, Canada. Ecology 33(1):31-40.

Pollen profiles from eleven peat sections in the Grande Prairie-Lesser Slave Lake region of Alberta reveal that pine (*Pinus*) is more abundantly represented in the western part and becomes less abundant eastward with the exception of the easternmost section which lies on the pine-forested sandy glacial outwash north of Edmonton. The pollen proportion averages of pine decrease eastward while those of spruce (*Picea*) conversely increase. In nine sections pine is recorded to its maximum at the top while spruce attains its maximum at some point between the top and bottom. The expansion of pine in the upper levels may reflect the influence of fire and a drier climate in more recent time. Fir (*Abies*) is only slightly represented and its trends do not seem to be significant. The absence of aspen (*Populus*) pollen, due to its poor preservation, undoubtedly distorts the pollen profiles and presents an incomplete picture of forest succession.

The chronology of the recorded forest history is not clear because it is not known whether the region was covered by the Late Wisconsin ice, although vast lakes in the region probably prevented extensive forest development until postglacial time. The relative shallowness of the muskegs does not point to great antiquity, and they may have developed since the warm, dry maximum. The region was postglacially invaded by species of the subalpine Cordilleran forest, the boreal forest and the grassland. Species of the Cordilleran and boreal forests may have persisted in refugia in northeastern British Columbia and central Yukon during the last glaciation.

A.S.

341. HANSEN, H.P. 1955. Postglacial forests in south central and central British Columbia. American Journal of Science 253(11):640-658.

Pollen analyses were made of 25 peat sections obtained in summers 1947 and 1952 (under grants from the American Philosophical Society and the Arctic Institute of North America). Present vegetation of the region and postglacial vegetation as revealed in the peat sections are described, and an interpretation of postglacial climate and chronology is given. Significant chronological correlation was found with postglacial thermal maximum of south central Oregon and eastern Washington. The thermal maximum may have occurred about 6,000 years ago, with the xerothermic interval lasting from 7,500 to 3,500 years ago.

A.B.

342. HARE, F.K. 1951. Some notes on post-glacial climatic change in eastern Canada. Royal Meteorological Society, Canadian Branch 2(7):8-18.

This paper reviews the several methods in use for the reconstruction of past climates and discusses the evidence so far obtained by each method in eastern Canada. It presents little new material. The methods discussed are : i) Pollen Analysis; ii) Tree-ring Analysis; iii) Statistical Analysis of climatological Data. Some attempt is also made at general conclusions as to the post-glacial changes of climate east of Hudson Bay and the Great Lakes.

Thomas

343. **HARE, F.K. 1973. On the climatology of post-Wisconsin events in Canada. Journal of Arctic and Alpine Research 5(3), Part 1:169-170.**

The surviving glacial ice of the Northern Hemisphere lies under the eastern limbs of the troughs of the bipolar wave in the circumpolar westerlies. Other distributions such as forest-tundra and the arctic tree line are closely related to the Arctic front, which is also deformed by the bipolar wave. There is some evidence that in the post-Wisconsin warming the *phase* of these waves was essentially the same as today, and that quite small changes in amplitude are sufficient to account for most climatic variations since that time.

A.A.

344. **HARE, F.K. 1976. Late Pleistocene and Holocene climates: some persistent problems. Quaternary Research 6(4):507-517.**

The author identifies..."some disturbing and persistent problems that tend to defy solution." Three broad areas of uncertainty are discussed: (1) the post-Wisconsin retreat phase; (2) energetics of the post-Wisconsin phase; and (3) bioclimate of the displaced biota. The author reviews present knowledge of paleoclimates in North America, including further unanswered questions and conflicting evidence. There is a need for more cross-specialist pooling of evidence and experience in paleoclimatological research.

A.B.S.

345. **HARE, F.K. 1981. Future climate and the Canadian economy. In: Climate Change Seminar Proceedings. Regina. March 17-19. Canadian Climate Centre, Downsview. pp. 92-122.**

"In this keynote address I have chosen ... to concentrate on the possibility of future climatic change, chiefly from the carbon dioxide effect, and the possible consequences for our economy."

"The CO_2 question is not yet well articulated, but this much can be said: there will be benefits as well as costs for most societies. It is not clear whether Canada will lose or gain from the changes, if they eventuate. It is by no means certain, indeed, that they will ever happen. And if they do we do not know in detail how drastic they will be, or how they will distribute themselves across the national map. All that scientists can advise at present is to be wary: the country should be on yellow alert."

"This means that we should work hard to understand and predict the impending changes, and to monitor the atmosphere, oceans and biota so as to offset any hardships the changes may bring, and to exploit any opportunities created. If these things are done Canada may on balance profit from the CO_2 effect."

"Since this is a world-wide problem, and since Canada's prosperity depends on foreign trade, we must also involve ourselves in international efforts to answer the same question. Participation in the World Climate Programme and similar efforts is not merely a duty; it is a defence of the national interest."

Excerpts

346. **HARINGTON, C.R. 1968. A Pleistocene muskox (*Symbos*) from Dease Lake, British Columbia. Canadian Journal of Earth Sciences 5(5):1161-1165.**

A *Symbos* skull fragment from Pleistocene deposits of northern British Columbia constitutes the first record of that genus for the province. In Canada, remains of this large muskox have been collected previously in western Yukon and southeastern Saskatchewan. Most of the other known specimens have been found in Alaska and the central United States, and the Canadian occurrences help to link these two areas of *Symbos* range. *Symbos* was adapted to warmer surroundings than *Ovibos* - perhaps a steppe or parkland environment.

The specimen described suggests that *Symbos* herds grazed on intermontane range in northern British Columbia during a warm period in the latter half of the Pleistocene Epoch. Only at such times would that area have been free from alpine glaciation.

A.A.+

347. HARINGTON, C.R. 1977. Marine mammals in the Champlain Sea and the Great Lakes. In: Amerinds and their Paleoenvironments in Northeastern North America. Edited by: W.S. Newman and B. Salwen. Annals of the New York Academy of Sciences 288:508-537.

Analyses of fossil mollusks, the remains of invertebrates and vertebrates, fossil pollen, and plant macrofossils, indicate "the Champlain Sea environment was probably very much like that of the present Gulf of St. Lawrence, where many species that formerly inhabited the inland sea are still found. A major trend in the history of the sea was that the water became increasingly shallower, warmer, and less salty as time progressed. Water was generally fresher in the western and southern extremities of the sea than elsewhere." It is within this framework that the author discusses "the kinds, distribution and relative abundance of marine mammals in the Champlain Sea as indicated by fossils, not neglecting paleoenvironmental clues that are occasionally brought to light by the evidence."

A.B.S.

348. HARINGTON, C.R. 1978. Quaternary vertebrate faunas of Canada and Alaska and their suggested chronological sequence. Syllogeus 15:1-105.

Thirty-one Canadian and Alaskan Quaternary vertebrate faunas, ranging in age from about 1,800,000 to 5,000 years, are reviewed against a background of some of the major characteristics of the ice age in northern North America, and an attempt is made to outline their chronological sequence. For each fauna a list of species is given, and the following points are dealt with where possible: suggested geological age, stratigraphy at the site, palaeoenvironmental implications, and pertinent references. Where interest seems to warrant it, single species or specimens are discussed. Radiocarbon dates on bone from Pleistocene vertebrates or from associated organic material are included.

In conclusion, significant features of the faunas are reviewed from oldest to youngest and in relation to several faunas of similar age from northeastern Siberia and the Great Plains of the United States. Early man is mentioned briefly. Evidence suggests that people were present in the northern Yukon about 27,000 years ago, and perhaps even earlier than 32,000 years ago in southern Alberta.

A.A.

349. HARINGTON, C.R. 1980. Faunal exchanges between Siberia and North America: evidence from Quaternary land mammal remains in Siberia, Alaska and the Yukon Territory. Canadian Journal of Anthropology 1(1):45-49.

In this discussion, I wish to shift the focus in order to describe mammalian relationships between Eurasia (often western Beringia, i.e. unglaciated areas of northeastern Siberia) and North America (often eastern Beringia, i.e. unglaciated areas of Alaska and the Yukon) during the Quaternary, not neglecting information that may be derived from some of the larger-sized species.

On the basis of fossils collected from sites in the Yukon alone, the movement of mammals from Eurasia to North America has been extensive. I estimate that 75 percent of 62 species of

Quaternary land mammals were derived from Eurasia; the remainder having come from southern North America (Harington, 1977). It is likely that the Eurasian species entered by a series of Bering land connections that occurred during glacial maxima.

Excerpts

350. **HARINGTON, C.R. 1980. Radiocarbon dates on some Quaternary mammals and artifacts from northern North America. Arctic 33(4):815-832.**

Nine radiocarbon dates on five genera of Quaternary mammals from northern North America are discussed. Of particular interest are: (a) a 29,000-year-old artifact from the Yukon Territory; (b) the first evidence that steppe mammoths (*Mammuthus columbi* or *M. armeniacus*) occupied eastern Beringia during the peak of the Wisconsin glaciation; (c) dates indicating that saiga antelopes (*Saiga tatarica*) and Yukon short-faced bears (*Arctodus simus yukonensis*) occupied the Yukon-Alaska region in mid-Wisconsin time; (d) dates indicating that bison (*Bison* sp.) lived near the arctic coast of the Northwest Territories, and tundra muskoxen (*Ovibos moschatus*) lived in the western Yukon in late postglacial time; and (e) dates suggesting that tundra muskoxen have occupied the central Canadian Arctic Islands for the last 7000 years.

A.A.

351. **HARINGTON, C.R. 1980. The impact of changing climate on people in Canada; and the National Museum of Natural Sciences Climatic Change Project. In: Climatic Change in Canada. Edited by: C.R. Harington. Syllogeus 26:5-15.**

The author illustrates the impact of climatic change on the people of Canada by mentioning several examples. These include the changes in population of the Yukon Territory before the peak of the Wisconsin glaciation and at its close, the dry period in the Canadian prairies between 1928 and 1937, and the warming of the waters between Canada and Greenland between 1917 and 1940. Such examples constitute a strong argument for supporting a comprehensive research program on climatic change in Canada.

The goals and proposed methodology of the National Museum of Natural Sciences Project on Climatic Change are outlined.

A.B.S.

352. **HARINGTON, C.R. 1981. Pleistocene saiga antelopes in North America and their paleoenvironmental implications. In: Quaternary Paleoclimate. Edited by: W.C. Mahaney. Geo Abstracts, Norwich.** pp. 193-225.

Six fossils from central Alaska, one from northern Alaska and one from east of the Mackenzie Delta in Canada are referred to the saiga antelope (*Saiga tatarica*). This species seems to have dispersed from Eurasia as far westward as England, and as far eastward as northwestern Canada, during the late Pleistocene. The species became extinct in western Europe and North America toward the close of the last (Würm/Wisconsin) glaciation, but survives in central Eurasia. Because living saigas are particularly adapted to dry steppe-grasslands, it is likely that they crossed broad, steppe-like plains of the northern Bering Isthmus during glacial phases of the late Pleistocene. Presumably the kind of northern steppe to which they had adapted once extended eastward, up the Yukon River valley to central Alaska, and along the Arctic Coastal Plain to Baillie Islands in Canada. Saiga antelope remains appear to be useful paleoenvironmental indicators. They suggest the presence of steppe-like vegetation, generally low, flattish terrain, rather arid climatic conditions and above all, shallow snow cover.

A.A.

353. HARINGTON, C.R., and S. OCCHIETTI. 1980. Pleistocene eider duck (*Somateria* cf. *mollissima*) from Champlain Sea deposits near Shawinigan, Québec. Géographie physique et Quaternaire 34(2):239-245.

Study of a pelvic fragment -- probably that of a Common Eider (*Somateria* cf. *mollissima)* -- from marine littoral sediments near Shawinigan, Québec, indicates that a population of eiders occupied the northern shore of the Champlain Sea about 10 300 years BP. Food and habitat requirements of living Common Eiders appear to have been met in the Shawinigan area at that time. In other words the bird fossil is compatible with associated paleoenvironmental evidence.

A.S.

354. HARINGTON, C.R., and D.E. SERGEANT. 1972. Pleistocene ringed seal skeleton from Champlain Sea deposits near Hull, Quebec - a reidentification. Canadian Journal of Earth Sciences 9(8):1039-1051.

A seal skeleton from Champlain Sea deposits near Hull, Quebec, formerly identified as probably belonging to a young harp or harbor seal, actually represents a seven year old ringed seal. The skeleton was deposited *in situ*, probably during an early cold phase of the Champlain Sea about 12 000-11 000 yr B.P. The specimen suggests that fast ice existed near the western margin of the Champlain Sea during winter and spring.

A.A.

355. HARINGTON, C.R., and D.M. SHACKLETON. 1978. A tooth of *Mammuthus primigenius* from Chestermere Lake near Calgary, Alberta, and the distribution of mammoths in southwestern Canada. Canadian Journal of Earth Sciences 15(8):1272-1283.

Four species of mammoths are currently recognized as having lived in southwestern Canada during the Pleistocene. The most primitive, the southern mammoth (*Mammuthus meridionalis*), apparently entered North America from Eurasia via the Bering Isthmus during the Nebraskan glaciation, first appearing on the Canadian plains (Wellsch Valley) about 1.7 Ma ago. This species evidently survived in that region (Medicine Hat) until the following Kansan glaciation.

Of the remaining mammoths, the imperial (*Mammuthus imperator*) and the Columbian (*Mammuthus columbi*) seem to have been adapted to warmer conditions than the woolly mammoths (*Mammuthus primigenius*). Imperial mammoth fossils are known mainly from southeastern Vancouver Island. Possibly they preferred a moister type of habitat than Columbian mammoths. *M. imperator* may have lived in British Columbia and Alberta during the late Pleistocene.

Apparently Columbian mammoths were most common in the southern regions of the western Canadian provinces during the Yarmouth and Sangamon interglacials. They seem to have been particularly abundant in southern Alberta and Saskatchewan during the Sangamon interglacial. The fossils are suggestive evidence that cool grasslands with some shrubs and scattered trees covered the region at that time.

Fossils that can be definitely referred to woolly mammoths are relatively scarce in southwestern Canada, but are sufficient to show that tundra-like habitat (perhaps having some of the characteristics of arctic steppe (Matthews 1976) such as a high percentage of grasses) occurred in parts of southern Manitoba, Saskatchewan, and Alberta, and south-central and east-central British Columbia during parts of the Wisconsin glaciation. ...

pA.C.

356. HARINGTON, C.R., H.W. TIPPER, and R.J. MOTT. 1974. Mammoth from Babine Lake, British Columbia. Canadian Journal of Earth Sciences 11(2):285-303.

Remains of a partially articulated mammoth skeleton were exposed during stripping operations at a mining site on Babine Lake, British Columbia. The bones lay in silty pond deposits in a bedrock depression, and were overlain by a thin layer of gravel and a thick layer of glacial till. Although no molar teeth were found, limb proportions show that the specimen was a large mammoth, like the Columbian mammoth (*Mammuthus* cf. *M. columbi*). Two radiocarbon dates of 42 900 ± 1860 yr B.P. and 43 800 ± 1830 B.P. on wood from the silty fossiliferous layer, and another of 34 000 ± 690 yr B.P. on mammoth bone suggest that the animal sank in sticky pond deposits and died there. Paleobotanical evidence indicates that, during this part of the Olympia Interglaciation, the vegetation near Babine Lake was similar to present shrub tundra just beyond the treeline in northern Canada.

A.A.

357. HARMON, R.S. 1975. Late Pleistocene climatic variations in the vicinity of the Columbia Icefields, Banff National Park, Alberta. Geological Society of America, Abstracts with Programs 7(6):773-774.

Castleguard Cave runs beneath the southcentral portion of the Columbia Icefield and acts as a drainage route for glacial meltwater. It contains a complex suite of clastic and chemical sediments which show evidence of multiple phases of deposition and erosion attributed to the growth and decline of the Columbia Icefield in response to cyclic changes in Pleistocene climate.

Calcite speleothems from the cave give U/Th ages of 1300, 2700, 8000, 55,000 124,000 and 93,000-154,000 years BP. Together with other dated Canadian speleothems these ages suggest that speleothem growth is largely restricted to periods of warm (interglacial) climate.

The single speleothem indicating continuous growth from 93,000-154,000 years BP was also analyzed for O^{18}/O^{16} and C^{13}/C^{12} ratios and found to be an equilibrium deposit. An axial traverse of the specimen exhibits cyclical $\delta\ O^{18}$ variations with $\delta\ O^{18}$ minima interpreted as temperature maxima. Periods of warm climate are recorded at 105,000, 120,000 and 145,000 years BP, with only the 105,000 event exceeding $\delta\ O^{18}$ values of speleothems presently forming in the cave. This paleoclimate record is in excellent agreement with the speleothem record from temperate areas of North America and broadly comparable to the marine paleoclimate record.

A.A.

358. HARMON, R.S., D.C. FORD, and H.P. SCHWARCZ. 1977. Interglacial chronology of the Rocky and Mackenzie Mountains based upon ^{230}Th-^{234}U dating of calcite speleothems. Canadian Journal of Earth Sciences 14(11):2543-2552.

Fifty-four ^{230}Th-^{234}U ages for 36 different speleothems (calcium carbonate layers deposited in caves) from mountain karst areas of western North America (Nahanni region, Northwest Territories; Columbia Icefield region, Alberta and British Columbia; Crowsnest Pass area, Alberta and British Columbia; Bear River Range, Utah) cluster into five distinct age groups. Interpreting episodes of speleothem deposition to correspond broadly to periods of interglacial climate, it is possible to construct a general picture of climatic change in the Rocky and Mackenzie Mountains between 41°N and 62°N during the past 350,000 years. Thus, interglacials are recognized at: (1) present to about 15,000 years B.P.; (2) 90,000 to 150,000 years B.P.; (3) 185,000 to 235,000 years B.P.; (4) 275,000 to 320,000 years B.P.; (5) >350,000 years B.P. These interglacials agree well with periods of high sea stand and warm climate observed in the marine paleoclimatic record.

C.R.H.

359. HARMON, R.S., P. THOMPSON, H.P. SCHWARCZ, and D.C. FORD. 1978. Late Pleistocene paleoclimates of North America as inferred from stable isotope studies of speleothems. Quaternary Research 9(1):54-70.

Some speleothems ($CaCO_3$ cave deposits) can be demonstrated to have been formed in oxygen isotopic equilibrium with their parent seepage waters and thus a record of relative fluctuations in depositional temperature can be obtained from the $\delta\ ^{18}O$ variations in successive growth layers of such deposits. These temperature fluctuations reflect variations in the average annual air temperature at the surface above the cave, and therefore permit inference of past continental climate changes. Equilibrium deposits have been obtained from caves in San Luis Potosi, Bermuda, Kentucky, West Virginia, Iowa, and Alberta, ranging in age from 200,000 years BP to the present, as determined by $^{230}Th/^{234}U$ dating of the speleothems. The $\delta\ ^{18}O$ time curves for the six sites show the following synchronous climatic fluctuations: warm periods from 190 to 165 and from 120 to 100 Ka, at 60 and 10 Ka, and cold periods from 95 to 65 and from 55 to 20 Ka. The periods of thermal maxima correspond in time to the interglacial periods of the marine foraminiferal isotopic and faunal temperature records and to periods of high sea stand as observed from radiometric dating of raised coral reefs. Maxima and minima in insolation appear to be synchronous with this record as well.

A.A.

360. HARPER, F. 1962. Changes in climate, faunal distribution, and life zones in the Ungava Peninsula. Polar Notes 3:20-41.

It is beyond question that a definite change of climate has taken place in the Ungava Peninsula and elsewhere during the past four decades or so, with various resulting changes in faunal distribution and perhaps slowly developing changes in floral distribution as well.

When Merriam originated his life-zone theory, he did not, probably, anticipate that conditions would presently arise, in the form of an ameliorating climate, whereby that theory would be so dramatically tested and perhaps corroborated. Birds and other animals, in their recent northward advances, have, at the very least, demonstrated their responsiveness to changing temperatures. Until such a change occurred, there was no satisfactory means of testing the validity of the theory.

Despite the deficiencies of Merriam's theory and the criticisms to which it has been subjected by Kendeigh (1932; 1954) and others, it still retains a certain usefulness in defining the ranges of animals and plants. Testimony as to that usefulness is furnished by the republication of his map in such recent works as that of Anderson (1947) on Canadian mammals and that of Muesebeck, Krombein, and Townes (1951) on North American Hymenoptera. It is doubtless significant that such botanists as Hustich (1949; 1951), Raymond (1950), and Rousseau (1952) and such a geographer as Hare (1950) recognize major zonal divisions in the Ungava Peninsula that correspond broadly with Merriam's life zones.

Each of the boreal zones (Arctic, Hudsonian, and Canadian) stretches across Canada as far west as the Rockies without very abrupt or striking changes in its flora or fauna; and it is evident that Merriam's theory holds better for these than for the austral zones (Transition, Upper Austral, and Lower Austral). The latter, being interrupted in the Midwest by vast areas of prairies and plains, naturally fails to exhibit a transcontinental uniformity of flora and fauna comparable with that in each of the boreal zones. It is also evident that human agencies have had, up to the present time, a far less serious and disturbing effect upon original conditions in the boreal zones than in the austral zones.

The late Joseph Grinnell maintained a general faith in the concept of temperature-delimited life zones. In a joint paper by Hall and Grinnell (1919:38) we read: "The idea that life-zones are altitudinal or latitudinal is correct only in a very general way or incidentally. They are instead, primarily biologic, that is, they are composed of and determined by a certain assemblage of plant and animal species, and are affected by altitude or latitude only as these modify the climate, more especially the temperature during the critical periods of an organism's existence."

Grinnell writes further (1927:324-325): "The gist of C. Hart Merriam's life-zone tenet, temperature control, is now receiving confirmation upon the basis of a vastly greater accumulation of meteorological figures and distributional facts than were at his disposal 25 to 35 years ago". At the same time he points out the need of recognizing rainfall and plant associations as factors in the distribution of birds.

The present communication is not to be regarded as an unqualified brief on behalf of isotherm-delimited life zones. It poses, rather than settles, the question of the geographical stability of such zones. It is little more than an attempt to show how various animals (particularly birds) seem to have pushed their ranges northward during (and presumably as a result of) the recent amelioration of the climate, keeping pace with a northward advance of the life zones of which they are characteristic species. The important role of climate in determining the distribution of living organisms is thus emphasized anew. The promptness with which at least some of the more mobile vertebrates have responded to the recent climatic changes is particularly evident and notable.

A.S.C.

361. HARRIS, A.H., and P. MUNDEL. 1974. Size reduction in bighorn sheep (*Ovis canadensis*) at the close of the Pleistocene. Journal of Mammalogy 55(3):678-680.

Ovis "fossil specimens from southern Canada and interior United States dating from before about 10,000 radiocarbon years ago average considerably larger than those from after that date." The authors suggest that environmental deterioration resulted in a general selection for smaller size at the close of the Pleistocene. "The present subspecies, then, would be a reflection of this selection, other selective adjustments more regional in nature, and an increase in geographic isolation as suitable habitat decreased in Holocene time."

A.B.S.

362. HARRIS, S.A. 1967. Areal distribution of the various combinations of Quaternary climates. Cahiers de géographie de Québec 11(22):55-62.

In this paper, the apparent extent of various simple combinations of climatic variations during Quaternary times are outlined and some of their implications in physical geography are discussed.

pA.A.

363. HARRISON, J.E. 1976. Dated organic material below Mazama tephra: Elk Valley, British Columbia. Geological Survey of Canada Paper 76-1C:169-170.

Two samples were collected from a horizontal organic layer, producing dates of 11 900 ± 100 years B.P. (GSC-2142) and 12 200 ± 160 years B.P. (GSC-2275). Pollen analysis of the first sample "revealed an assemblage dominated by pine (*Pinus*), with only minor amounts of spruce (*Picea*), western hemlock (*Tsuga heterophylla*), birch (*Betula*), alder (*Alnus*), grasses (Gramineae), composite (Liguliflorae), and members of the evening-primrose family (Onagraceae)." Occurrence of a forest fire was indicated by the charred nature of the woody material. The site was deglaciated some time before 12 000 B.P. This date may further serve as a minimum date for deglaciation of the lower and middle Kananaskis Valley.

A.B.S.

364. HARVEY, L.D.D. 1980. Solar variability as a contributing factor to Holocene climatic change. Progress in Physical Geography 4(4):487-530.

... This review evaluates in three ways the hypothesis that solar variability contributed to Holocene climatic change: by compiling global evidence from proxy climatic indicators for the last 7500 years; by critically examining evidence for and against solar variability during the last 7500 years, and finally by examining possible mechanisms of a solar variability-climate relationship which previously have not been considered in a discussion of Holocene climate. The review closes with a brief discussion of the possible relevance to man of a knowledge of the causes of Holocene climatic change.

pA.A.

365. HATTERSLEY-SMITH, G.F. 1960. Studies of englacial profiles in the Lake Hazen area of northern Ellesmere Island. Journal of Glaciology 3(27):610-625.

Reports on the glaciological research of the Canadian IGY expedition in 1957-1958. The method of nourishment of the icecap and of Gilman Glacier was studied in pit and bore hole profiles above and below the equilibrium line, which was found at about 1,200 m. elevation. Between approx. 1,450 and 2,000 m., accumulation is by firn formation; between 1,280 and 1,450 m., interfingering of firn and superimposed ice occurs. At 1,800 m. the mean annual accumulation over the past 20 years is estimated as 12.8 g. cm^{-2}. The budget deficit of Gilman Glacier during the last 20 years is discussed, noting possible climatic trends.

A.B.

366. HATTERSLEY-SMITH, G.F. 1960. Some remarks on glaciers and climate in northern Ellesmere Island. Geografiska Annaler 42(1):45-48.

Reviews work on glacial history and post-glacial climate of this area, especially in relation to the recent theory of ice ages of Ewing and Donn. Conditions at time of maximum ice cover and climatic changes resulting in subsequent glacial retreat and fluctuation are postulated. An open Arctic Ocean would probably be conducive to a milder and moister climate; a rise in temperature at higher (accumulation) elevations in northern Ellesmere might bring about greater precipitation and advance of glaciers.

A.B.

367. HATTERSLEY-SMITH, G.F. 1963. Climatic inferences from firn studies in northern Ellesmere Island. Geografiska Annaler 45(2-3):139-151.

Presents results of studies made in 1958 and 1961 on Gilman Glacier and on the northern Ellesmere icecap, as part of the Canadian IGY and subsequent programs. The firn stratigraphy is described for an elevation which is close to the boundary between the dry snow and the percolation facies. Evidence of increased summer melting on the icecap in the last 35 yrs. is correlated with a 2°C. increase of mean summer temperature at Upernavik on the west coast of Greenland, to show that the climatic warming of the late 1920s and the 1930s in central West Greenland and elsewhere also affected northern Ellesmere Island, where no continuous meteorological records were kept before 1948. The Upernavik record, on the other hand, goes back to 1874, with minor gaps, and is a useful indicator of conditions over a fairly wide area.

A.B.

368. HATTERSLEY-SMITH, G.F. 1969. Glacial features of Tanquary Fiord and adjoining areas of northern Ellesmere Island, N.W.T. Journal of Glaciology 8(52):23-50.

The former ice cover of northern Ellesmere is confirmed as much more extensive than the present, though the age of maximum glaciation is not known. In the Tanquary Fiord area, the conclusion is based on bathymetric data indicating considerable over-deepening of fiords, morphology of main valleys, and presence of moraines, erratics and glacial lake deposits at high levels. The fiord became free of glacial ice and peat was forming in the valleys at least 6500 yr ago. A long period of river erosion followed the main retreat of the ice. Within the last 4000 yr, glaciers advanced to re-occupy V-shaped valleys, and small icecaps were probably regenerated. In the last 900 yr, there has been little change in the terminal position of most major glaciers.

A.B.

369. HATTERSLEY-SMITH, G.F. 1972. Climatic change and related problems in northern Ellesmere Island N.W.T., Canada. In: Climatic Change in Arctic Areas During the Last Ten Thousand Years. Edited by: Y. Vasari, H. Hyvärinen and S. Hicks. Acta Universitatis Ouluensis Series A, Scientiae Rerum Naturalium 3, Geologica 1:137-148.

The Defence Research Board has supported interdisciplinary studies in northern Ellesmere Island since 1953. Drawing on some of the results of this work, I shall first summarize our limited knowledge of the times of onset of (i) the climatic warming leading to general deglaciation and (ii) the subsequent fluctuation towards cooler conditions that led to the growth of ice shelves off the north coast of Ellesmere Island. I shall then review the present status of the Ward Hunt Ice Shelf; describe the unusual oceanographic conditions in Disraeli Fiord that result from the presence of the ice shelf; and look briefly at the peculiar structure of certain glacial lakes in the same area. All these phenomena are directly or indirectly related to climatic change. It will be seen that present climatic cooling appears to be affecting the Ward Hunt Ice Shelf, and I shall provide evidence of the same trend affecting the Gilman Glacier and adjoining ice cap and of a parallel deterioration in sea ice conditions in Nansen Sound. Finally, it will be worth looking at the possible information on past climate that could be obtained from deep coring on one of the main ice caps of northern Ellesmere Island.

A.A.

370. HATTERSLEY-SMITH, G.F., and A. LONG. 1967. Postglacial uplift at Tanquary Fiord, northern Ellesmere Island, Northwest Territories. Arctic 20(4):255-260.

Constructs a postglacial uplift curve for the upper part of Tanquary Fiord from radiocarbon ages of marine shells and peat. Data show the head of the fiord to be clear of glacial ice by at least 6500 yr BP. During 6500-5000 yr BP isostatic uplift was at a rate of about 3.5 m/century and subsequently about 25 cm/century.

A.B.

371. HATTIE, S.A., and R.A. HORNSTEIN. 1963. Recent precipitation fluctuations and trends in the Atlantic Provinces. Department of Transport, Meteorological Branch CIR-3864, TEC-475:1-9.

Five-year running averages of seasonal and annual precipitation are plotted, and thirty-year averages of these quantities are tabulated for a number of stations in the Atlantic Provinces.

At all stations studied except Truro, N.S., an increasing trend appears to have been in progress during the last twenty-five to forty-five years. There are also periodic short-term variations with eight to fifteen years between successive maxima and minima. At Truro there are fluctuations with a period of about thirty years which are more noticeable than either short-term or long-term variations.

A.A.

372. **HAWKES, B.C. 1979. *Fire history and fuel appraisal of Kananaskis Provincial Park, Part I.* In: Proceedings of the International Fire Management Workshop. Canadian Forestry Service, Information Report NORX-215. pp. 80-87.**

The fire history of Kananaskis Provincial Park is not as complex as that of lower-elevation montane forests in the Rocky Mountains. The area east of Lower Kananaskis Lake (facility zone) is covered by extensive tracts of even-age lodgepole pine regeneration as a result of fires in 1920, 1890, and 1858. Most fires in Kananaskis Provincial Park were large (+1000 ha) and of medium to high relative fire intensity (derived from height of fire scars, type of stand replacement, and more recent fire reports). The park has a catastrophic fire regime where "natural" fires are usually conflagrations, killing the overstory and understory of the forest. Low-intensity surface fires usually have occurred on the edges and backing sections of large fires.

The results indicate that the park has had 11 major fires since 1712, with an average of 21 years between fires. A total of 17 fires occurred form 1712 to 1920, with a mean fire return interval (MFRI) of 14 years and a range of 3-38 years. The last major fire was in 1920.

The total number of fires since 1712 and the MFRI's for four areas of Kananaskis Provincial Park are listed. The lower Kananaskis Valley has had over twice the number of fires as the other areas. This area is where all the park facilities are being built.

Burn direction of major fires in the lower Kananaskis seems to be related to the prevailing wind patterns. Most fires have burned through the area east of the Lower Kananaskis Lake. Fire reports of more recent large fires in the Kananaskis Valley indicate that spotting can occur up to 5 km (3 mi) ahead of the fire. This kind of fire behavior expected from large fires in Kananaskis must be reckoned with by resource planners in developing the valley.

Excerpts

373. **HAZELL, S.D. 1978. Two late Quaternary pollen diagrams from southeast British Columbia. American Quaternary Association, National Conference, Abstracts 5:167.**

Sediment cores were lifted from two lakes, 2 km apart, in the Purcell Mountains (50°45'N, 116°20'W), about 200 km west of the ice-free corridor. The lakes are at an elevation of 1,130 m, surrounded by a montane forest dominated by *Pinus contorta*, with *Picea*, *Abies*, and *Pseudotsuga*.

The pollen diagrams of the two lakes are similar. After deglaciation, there is a late-Pleistocene *Pinus-Artemisia*-Gramineae zone, followed by a previously unreported early Holocene *Pinus-Juniperus* zone. *Betula* and *Alnus* replace *Juniperus* around 7,000 years BP. From the mid to late Holocene, *Picea, Abies, Pseudotsuga*, and *Tsuga* percentages increase while *Betula* percentages decrease.

The pollen analysis suggests that after deglaciation there was a steppe-tundra, dominated by *Artemisia*, with scattered *Pinus* stands. This was followed by a forest-tundra, dominated by *Pinus* and *Juniperus*. During the past 7,000 years, there has been a closed-canopy, *Pinus* dominated forest, with *Picea*, *Abies*, and *Pseudotsuga* gradually increasing in importance.

A detailed analysis of the 3 cm thick Mazama ash showed elevated percentages of *Artemisia* and Gramineae pollen in the upper 1 cm of ash and 3 cm of overlying sediment; Mehringer et al. (1977) found that high *Artemisia* percentages did not persist to overlying sediment. My analysis suggests that the ash deposition enabled *Artemisia* steppe to expand in extent for up to 100 years at the expense of forest.

A.A.

374. **HEBDA, R.J., and G.E. ROUSE. 1979. Palynology of two Holocene cores from the Hesquiat Peninsula, Vancouver Island, British Columbia. Syesis 12:121-130.**

Cores from Village Lake and Whicknit meadows on Hesquiat Peninsula were analysed for palynomorphs as part of an archaeological investigation. The palynologic results show a definite and interesting series of events for the eastern Hesquiat Peninsula during the last 2760 ± 80 years. A gradual shift occurred from marine to brackish to freshwater conditions in Village Lake, correlated with progressive emergence of the immediate area, and possibly of the entire peninsula. The shift to a freshwater regime was accompanied by significant changes in vegetation around the lake basin. The early vegetation consisted of a hemlock-spruce forest with chenopods, grasses, and *Ambrosia* inhabiting the salt marshes and beaches. As uplift proceeded and saltwater influence decreased, cedar stands developed around the basin, and the yellow water lily (*Nuphar*), pond-weed (*Potamogeton*), buck-bean (*Menyanthes*), and sedges became the chief inhabitants of aquatic habitats. From the paleoecologic changes and the basal date, the minimum late Holocene uplift for this area has been .11 m/century. This sequence provides a reference to which the development of other small coastal lakes and surrounding lowlands can be compared. On the flat lands of the interior of the peninsula, *Myrica*-dominated boggy meadows developed about 1080 ± 110 years ago.

A.A.

375. **HENOCH, W.E.S. 1971. Estimate of glaciers secular (1948-1966) volumetric change and its contribution to the discharge in the Upper North Saskatchewan River Basin. Journal of Hydrology 12(2):145-160.**

The recent trend of glacier recession in the Rocky Mountains began in the late 19th century. Since that time numerous studies of glaciers have been made but estimates of glacier volume decrease and the resultant increase in river discharge are lacking.

Quantitative measurements show that glacier volume loss in the Upper North Saskatchewan River Basin during the period 1948-1966 was $1000 \times 10^6 m^3$. This is approximately 4% of the total discharge determined from the records of the hydrometric stations at Saskatchewan Crossing and Mistaya River.

A.A.

376. **HERMAN, Y. 1978. Late Cenozoic paleoceanographic events in the Arctic. Geological Society of America, Abstracts with Programs 10(7):420.**

Deep-sea foraminiferal records and oxygen isotope data have been used to reconstruct oceanic climates of the Arctic during the last 4 m.y. Magnetic stratigraphy and biostratigraphic correlations provide the time control points and the time framework. Frigid, polar climates were established in the Arctic 4 m.y. ago; the low abundance of open ocean fauna between 4 and 2.5 m.y. BP appears to be due to post-depositional solution rather than to lack of productivity. Approximately 2.5 m.y. ago an abrupt change occurred in the hydrologic regime of the basin and was maintained almost continuously until ~ 0.7-0.9 m.y. BP. In addition to cold water species, temperate-subarctic, low-salinity tolerant planktonic forms populated the sea. Cores raised from the crest of the Alpha Cordillera contain abundant coarse ice-rafted detritus, and large percentages of shallow water forams, endemic to continental shelves, suggesting active ice-shelf and iceberg sediment transport to the central Arctic. During the last ~ 0.7-0.9 m.y., a time of marked global temperature fluctuations, the cold Arctic surface water underwent mainly salinity oscillations: The temporal absence of fauna was probably due to reduced productivity, a consequence of marked density stratification brought about by low salinities. Global temperature fluctuations appear to have been roughly synchronous, however, the expression of these fluctuations differs in various oceanic regions. While ice-rafting is a reliable indicator of glacial conditions in subpolar marine sediments in the Arctic it may be most abundant during deglaciations and early phases of interglacials.

A.A.

377. HEUSSER, C.J. 1955. Pollen profiles from the Queen Charlotte Islands, British Columbia. Canadian Journal of Botany 33(5):429-449.

Five peat sections were excavated from muskegs on Langara, Graham, and Moresby Islands of the Queen Charlottes with the primary purpose of reconstructing the postglacial plant succession and associated climatic and physiographic alterations. A secondary purpose was to support or disprove the geological and zoological data favoring the existence of refugia in which biota survived from preglacial or interglacial time. The oldest pollen record tends to support this contention. The record is older than any derived from sections heretofore studied on the northwest coast. Twenty-three plant entities are represented in the bottom sediments below the lodgepole pine maximum which in these other sections marks the oldest peat. In addition, 27% of the coniferous pollen at the base of the section is constituted of climax forest trees, thus implying the presence of long-established forest when pollen sedimentation began. The number and kinds of pollen in the basal peat favour the interpretation that vegetation persisted in refugia through at least the last glaciation. The pollen profiles further corroborate earlier findings for changes in land-sea level relations and for the following postglacial climatic sequence: early cool-moist, warmer and drier (thermal maximum), and late cooler and wetter.

A.A.

378. HEUSSER, C.J. 1956. Postglacial environments in the Canadian Rocky Mountains. Ecological Monographs 26:263-302.

Glacier variations and pollen profiles provide evidence for reconstructing the postglacial environments in the Canadian Rocky Mountains. The area of investigation is constituted by Robson, Jasper, Banff, and Yoho Parks which are situated along more than 250 mi. of the continental divide in the provinces of Alberta and British Columbia.

The region is one of massive mountains consisting almost entirely of sedimentary rock that has been thrust and faulted into blocks and folds. Glaciation by the Cordilleran Glacier Complex affected much of the region although the higher peaks were not overridden by ice.

Data were gathered from 12 glaciers between the vicinity of Mt. Robson to the northwest and that of Kicking Horse Pass at the southeast, a distance of 175 miles.

Peat sections were removed from 4 deposits by means of a Hiller borer fitted with additional shafts. The Jasper section was longest at 4.0 m in length and consisted of sedge peat overlying limnic sediments in which a stratum of volcanic ash was present at 3.0 m depth. The pollen sequence shows pine-spruce-fir constituting the early record and succeeded by pine-spruce-Douglas fir, thence pine-spruce-fir, and finally pine-spruce-western hemlock.

The environments implied by the pollen and glacier data are represented by intervals of cool and moist climate during the early and late postglacial with the thermal maximum interposed. The late postglacial is coincident with glacier rejuvenation at which time a series of maxima was attained in the seventeenth, eighteenth, and nineteenth centuries. The latter is thought to have been the most dynamic since in several instances it exceeded, at least in part, positions reached by earlier advances. After about 1930, recession, which has been conspicuously progressive from the second half of the nineteenth century, has been more pronounced. This trend is in keeping with the meteorological record which shows warming and a decrease in precipitation from the late 1800s up until the late 1930s. Since the early 1940s temperatures have fallen and precipitation risen into the present decade. A lag in the response of glaciers to this most recent climatic change seems apparent as all termini visited in 1953 were retreating. Elsewhere in North America certain glaciers appear to be undergoing regeneration, particularly those in the Pacific Northwest.

pA.S.

379. HEUSSER, C.J. 1966. Polar hemispheric correlation: palynological evidence from Chile and the Pacific Northwest of America. In: World Climate from 8000 to 0 B.C. Edited by: J.S. Sawyer. Royal Meteorological Society, London. pp. 124-141.

Pollen diagrams and peat stratigraphy of sections from north Pacific America (46°-59°N) and southern Chile (41°30'-46°40'S) are brought together for the purpose of constructing a working model to serve as the basis for comparing the climates of temperate latitudes in the polar hemispheres during the late-glacial and post-glacial. The model, thus far developed, shows a general parallelism for the climatic trends in these regions, and within the limits of the radiocarbon chronological control available, the times of change appear to run in harmony.

The late-glacial, which dates from 15,000-16,000 B.P. consists of three zones, partitioned on the basis of western European stratigraphy. Average summer temperature in zone I (=Older Dryas) was c 11°C, being depressed c 5° compared with the present; in zone II (=Alleröd) it increased 3-4°; and in zone III (=Younger Dryas) it fell again to c 11°. Humidity, however, was contrasted between the regions during the late-glacial. Zones I and III which were wetter compared to zone II in Chile were drier in north Pacific America by comparison to zone II.

The post-glacial begins 10,000-10,500 B.P. and its five zones follow the stratigraphic scheme proposed by Blytt and Sernander for southern Scandinavia. The climate of zone IV (=Pre-Boreal) was cool and moist with temperatures 3-5° colder than the present, but warmer conditions ensued, reaching maxima of 1-2° warmer than today in zone V (=Boreal). Sites of greater continentality appear to have had less humid climate whereas oceanic sites continued to be wet. Zone VI (=Atlantic) was wetter and cooler than the previous interval by c 2-3° except at low elevations near the ocean where temperature changes were not recognizable. A uniformly drier climate which was also somewhat warmer prevailed in zone VII (=sub-Boreal) but changed rather abruptly at the opening of zone VIII (=sub-Atlantic), at about 2500-3000 B.P., becoming generally wet and on the order of 2-3° cooler.

A.S.

380. HEUSSER, C.J., L.E. HEUSSER, and S.S. STREETER. 1980. Quaternary temperatures and precipitation for the northwest coast of North America. Nature 286(5774):702-704.

Palynologists utilize present-day pollen rain to interpret the climatic setting of pollen records from Quaternary deposits. Analogues are sought which relate the present with the past. Because climatic conditions at mid-latitudes during the Quaternary were diverse, often ranging from a tundra type at one extreme to a closed forest type at the other, a modern data set should cover the extremes of vegetation and climate expected during this time. For interpreting climatic parameters from Quaternary pollen in land and marine cores, we calculated a pair of regression equations relating modern pollen rain from the Pacific coastal forest and tundra to mean July temperature and mean annual precipitation at a series of sites from the Aleutian Islands to northern California. We describe here how application of these equations to Quaternary pollen profiles from western Washington enabled us to quantify temperature and precipitation over the past ~ 80,000 yr.

The glaciation periods during the Pleistocene were cold and relatively dry with ameliorated moist episodes intervening. During the Holocene, coolness was associated with greater precipitation, and intervals of warmth were drier. This suggests that the prevailing mechanism controlling the climate on the northwest coast during the present interglaciation contrasts with the mechanism in effect during glaciation.

A.A.$^+$

381. HICOCK, S.R., A. DREIMANIS, J.E. ARMSTRONG, H.C. PALMER, and N.W. RUTTER. 1979. Pre-Fraser stratigraphy, Georgia Depression, British Columbia. Geological Society of America, Abstracts with Programs 11(7):443.

Paleomag., amino acid, $\delta 0^{18}$, and pollen studies of sub-Quadra sediments have confirmed correlations suggested by previous workers. The sequence of (oldest to youngest): Westlynn glaciation (Westlynn drift; Illinoian?), Highbury interglaciation (Mapleguard formation; Sangamon?), Semiahmoo glaciation (Dashwood drift; early-Wisconsin), and Olympia nonglacial interval (Cowichan Head Fm; mid-Wisconsin), is now established and the first three events and formations will soon be formalized. The Cowichan Head Fm. was previously defined by ^{14}C dates and lithostratigraphy. Pollen studies show that: Spruce (20%)>Pine (10)>Fir=Hemlock (3)>Doug. Fir (<1). Dashwood glaciomarine is correlated by similar patterns from six sections (5-10 m thick) of remanent magnetic INC and DEC, and polar wandering paths; by similar amino acid D/L ratios from aspartic (.35-.65), glutamic (.15-.3), leucine (.25-.4), phenylalanine (.3-.5), proline (.4-.75), and valine (.15-.25) and by AP proportions: Pine (30%)>Spruce (10)>Fir=Hemlock (5)>Doug. Fir (<1). The Mapleguard Fm. is correlated by pollen: Doug. Fir (12%)>Hemlock (9)>Pine (7)>Spruce=Fir (4). Noticeable deviations in INC and DEC curves from Dashwood glaciomarine may correlate with the Blake event; if true it pushes the Highbury/Semiahmoo boundary at least back to 110,000 BP in this area. Semiahmoo ice movements inferred from till fabrics and glaciotectonic structures suggest a model of valley glaciers feeding the St. of Georgia lobe which split to form the Puget and Juan de Fuca lobes. $\delta 0^{18}$ ratios from Dashwood marine molluscs at 8 sites contain negative values (-.67 to -6.37); reflecting freshwater influx) which become more positive down fiord valleys towards the St. of Georgia. The most positive values (.41-1.72) are near the St. of Juan de Fuca which leads to the open Pacific. The Georgia Depression appears to have been a closed marine basin during Semiahmoo deglaciation when meltwater flow was concentrated down major fiords into the Strait of Georgia, greatly reducing seawater salinity. AP studies agree with previous ones that the Highbury Interglaciation was at least as warm as present; that Semiahmoo deglaciation was cooler; and the Olympia was intermediate with fluctuating periods of cooler than to as warm as now.

A.A.

382. HICOCK, S.R., R.J. HEBDA, and J.E. ARMSTRONG. 1982. Lag of the Fraser glacial maximum in the Pacific Northwest: pollen and macrofossil evidence from western Fraser Lowland, British Columbia. Canadian Journal of Earth Sciences 19(12):2288-2296.

Pollen and macrofossil evidence from two sites in northwestern Fraser Lowland reveals that *Abies lasiocarpa - Picea* cf. *engelmannii* forest and parkland grew there about 18 000 years ago under cold humid continental conditions. *Taxus brevifolia* was also a significant constituent of this forest. This plant assemblage resembles the ESSF[1] Biogeoclimatic Zone of subalpine elevations in the northern interior of British Columbia (900-2250 m). Climate was probably cold with low to moderate rainfall and characterized by long, cold, wet winters and very short, probably dry, frost-free summers. Mean annual temperature was depressed about 8°C and the tree line was probably 1200-1500 m lower than today.

Fraser Lowland was probably removed from Pacific oceanic influence because the land-sea interface was located on the continental shelf to the west of Vancouver Island and Washington about the time of the last global glacial maximum, global depression of sea level, and Quadra Sand aggradation in the Pacific Northwest. Lowland glaciation was probably delayed because of insufficient precipitation in the drier macroclimate and the precipitation shadow created behind mountains on Vancouver Island and Olympic Peninsula. We speculate that, as Laurentide ice decayed, there was a northward shift of zonal weather patterns over the eastern Pacific, bringing very wet winters to the Fraser Lowland and providing moisture for rapid, extensive, Vashon glaciation, which culminated about 14 500 BP, lagging at least 3000 years behind the Laurentide glacial maximum.

A.A.

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[1] Ed. note: Stands for the Engelmann Spruce - Subalpine Fir Biogeoclimatic Zone.

383. HICOCK, S.R., K. HOBSON, and J.E. ARMSTRONG. 1982. Late Pleistocene proboscideans and early Fraser glacial sedimentation in eastern Fraser Lowland, British Columbia. Canadian Journal of Earth Sciences 19(5):899-906.

Three recently radiocarbon-dated tusk segments from eastern Fraser Lowland indicate Pleistocene proboscideans (probably mammoths) lived there between 22 700 and 21 400 years ago during early Fraser (for the Fraser Lowland) ice advance into the area. Palynomorphs from silty sand adhering to a tusk indicate the animals grazed on open grassy floodplain. Sedimentologic and altimeter studies of tusk-bearing gravel indicate an early Fraser sandur, at least 10-km long and deposited at the same time as Coquitlam Drift, formed in Chilliwack Valley at the same time that a sandur or kame terrace was deposited against the north side of Promontory Ridge. Probably about 21 000 years ago (the time of Coquitlam glacial maximum in western Fraser Lowland) ice blocked Chilliwack Valley, creating a glacial lake whose freshwater, *Pediastrum*-bearing, laminated silt has been observed up to 200 m asl. Stratigraphy and history of the area following deposition of the above gravels and silt are still uncertain without more chronologic control. However, proboscideans could have migrated southward and westward, away from ice advancing into Fraser Lowland, across ancestral Strait of Georgia via the Quadra sandur, and onto southeastern Vancouver Island to which earliest Fraser glacial ice probably advanced after 17 000 years BP.

A.A.

384. HILLAIRE-MARCEL, C. 1972. Note sur une population Pleistocène de *Mya arenaria* (Linné), St-Joseph-du-Lac, Québec. Palaeogeography, Palaeoclimatology, Palaeoecology 12:275-283.

The fossil population, on which this note is based was obtained from the littoral deposits of the Champlain sea in the vicinity of St-Joseph-du-Lac (Québec). It would appear to merit a special study as regards some characteristics of paleoecological interest. In addition to having been preserved in their vertical living position, the shells show a general orientation on the ventral side towards the bottom of the sedimentary slope. When the sand becomes coarser, they occur in a vertical burrow, perfectly preserved. A comparison of the fossil population with the living forms studied by Swan (1952a) in the Gulf of St Lawrence allows discussion of the conditions of life prevailing at that time.

A.A.

385. HILLAIRE-MARCEL, C. 1977. Les isotopes du carbone et de l'oxygène dans les mers post-glaciaires du Québec. Géographie physique et Quaternaire 31(1-2):81-106.

Preliminary investigations of isotopic compositions of faunas, sediments and calcareous concretions from the post-glacial seas of Quebec, permitted to define an average range of composition for each of them. The Goldthwait, Iberville and Tyrrell seas have compositions similar to those presently found in Arctic waters. On the contrary, closed basins, such as the Champlain Sea, show marked negative compositions which can be attributed to influx of melt-water and more generally, continental waters. The amplitude of the variations due to that factor masks isotopic changes brought about by temperature fluctuations. Systematic differences of composition exist between shallow and deep water faunas. Those can be related to the presence of water layers which have different salinity and temperature. The similarities in the isotopic composition range between the Champlain Sea and the present James Bay tend to indicate a gross similar hydrological system. Finally, the homogeneity of isotopic composition of calcareous concretions in each basin show that most of the concretions are formed shortly after deposition of the sediments. In addition, the isotopic data suggest that waters, at least the deeper waters, have a deficit in ^{14}C in most marine basins. This would yield greater ^{14}C ages for shells, compared to those obtained with continental wood in isotopic equilibrium with the atmosphere.

A.A.

386. HILLAIRE-MARCEL, C. 1980. Les faunes des mers post-glaciaires du Québec: quelques considérations paléoécologiques. Géographie physique et Quaternaire 34(1):3-59.

A paleoecological study of the fossil fauna of the post-glacial seas of Québec, with special attention on mollusks, permit the delineation of type-communities. These benthonic communities are distributed according to the depth, with small variations from the northern basins to the generally more brackish southern seas. Thus, epibiontic (epifaunal) communities living on coarse sediments are the intertidal *Mytilus edulis* community, and the deeper water *Hiatella arctica* community which may be subdivided in two sub-communities. The endobiontic (infaunal) communities living in sandy, silty or clayey shallow water sediments, include the *Mya arenaria* and *Macoma balthica* communities and the deeper water *Macoma calcarea* community which may be subdivided in three sub-communities. The *Portlandia arctica* community deserves a special status because it is mainly associated with glacio-marine muddy environments. These communities, which correspond to well-defined litho facies, very often succeeded each other in relation to the decreasing depth of the basins due to post-glacial rebound. Thus, they do not reflect climatic trends, but simply hydrological changes caused by shoaling of each basin. Occasionally, some "warm" water species migrated northward for a short period of time during middle or late Holocene. They reflect a slightly delayed climatic optimum in the Arctic.

A.A.

387. HILLAIRE-MARCEL, C., and R.W. FAIRBRIDGE. 1978. Isostasy and eustasy of Hudson Bay. Geology 6(2):117-122.

In the eastern Hudson Bay area, a "staircase" of 185 Holocene strandlines provides a continuous record of emergence from about 8,000 yr B.P. (sidereal) to the present. Ages were obtained from corrected radiocarbon analyses of shells and from application of a newly discovered 45-yr cycle in beach building that is presumed to be related to the "double Hale" solar cycle. Thus, we deduced a record of climatic storminess.

The mean curve of emergence confirms Andrews's model of glacio-isostatic uplift. Analysis of the residuals in the emergence curve can be transformed to an approximate eustatic curve, which shows some degree of coincidence with other sea-level curves derived from low latitudes as well as with several climatic indicators. The strandline analysis appears to be a powerful new tool for Holocene climate analysis and prediction.

A.A.

388. HILLAIRE-MARCEL, C., and S. OCCHIETTI. 1977. Fréquence des datations au ^{14}C de faunes marines post-glaciaires de l'Est du Canada et variations paléoclimatiques. Palaeogeography, Palaeoclimatology, Palaeoecology 21(1):17-54.

A statistical analysis of radiocarbon dates for 365 samples associated with postglacial marine deposits of Eastern Canada and New England, U.S.A., yield a non-random statistical distribution. This distribution pattern is explained by two principal controls (that are partly interdependent): (1) secondary eustatic fluctuations, creating relative stabilizations of the sea level with an uplifting land; and (2) more generally the climatic variations. Other factors involved may include: (1) limitations of ^{14}C dating method; (2) non-statistical sampling methodology adopted by the Quaternary geologists; (3) lack of intensive study of some of the marine basins; and (4) incidence of rapidly changing paleogeographic events (opening and shoaling of marine basins, glacial readvances and changes in the ice flow). The statistical appraisal of errors in published ^{14}C dates and the standard deviation, calculated with sliding means, enable us to screen out the influence of most of the non-climatic factors. With this technique, we are also able to draw a curve based on a general synthesis of all variations in ^{14}C dates distribution. In this way, the irregularities observed in the synthesis curve are now correlated with paleoclimatic and paleogeographic events that took place in Eastern Canada between 15,000 years B.P. to present. That curve shows a close correlation during the Holocene with other climatic indicators and gives some original information concerning the period 15,000-10,000 B.P. No attempt has been made to adjust radiocarbon years for two reasons: (1) lack of agreement between comparative curves prior to 7,000 B.P., and (2) lack of information concerning the effect of "old waters" on shell dates.

A.A.

389. **HILLAIRE-MARCEL, C., and S. OCCHIETTI. 1980. Chronology, paleogeography, and paleoclimatic significance of the late and post-glacial events in eastern Canada. Zeitschrift für Geomorphologie 24(4):373-392.**

In a tentative synthesis of statistical marine ^{14}C chronology, isostatic and eustatic movements, continental glacial features and post-glacial marine limits, the paleogeographic evolution during the late and post-glacial times in eastern Canada, with special reference to Quebec, is here reassessed. Publications on these data, and fieldwork by the authors, are used in the drawing of maps of isochrones of Laurentide ice retreat, maximum diachronous extension of post-glacial lakes and seas, emergence observed since 7,500 BP and of paleogeography at 10,000-10,500 BP. The post-glacial uplift of Quebec is reconsidered with new regional emergence curves. A time-space diagram from 15,000 to 8,000 BP indicates the main steps in the retreat of the Laurentide ice-sheet in eastern Canada and the associated marine episodes.

A.S.

390. **HILLAIRE-MARCEL, C., S. OCCHIETTI, L. MARCHAND, and R. RAJEWICZ. 1981. Analysis of recent climatic changes in Quebec: Some preliminary data. In: Climatic Change in Canada 2. Edited by: C.R. Harington. Syllogeus 33:28-47.**

As part of a project on the climate of Canada over the past 20,000 years, we were asked by the National Museum of Natural Sciences to carry out a study of recent climatic variations in eastern Canada, essentially on the basis of historical data. The first stage (Hillaire-Marcel et al. 1980) involved planning our research. This paper summarizes results obtained since 1977. Temperature data based on instrumental records for Montreal were compiled for the period 1840-1975 and compared with a corresponding series of records for the Toronto region. In conjunction with this, indirect information on climate, such as port activity at Montreal, was processed and correlated with the instrumental data. Finally, we developed programs for statistical processing and spectrum analysis of short chronological series. These programs allow us to isolate the tendencies underlying the chronological series, and, above all, to bring to light the cyclical nature of recurring events. The programs were tested, as a preliminary step, in the context of the sea level data and recorded levels of inland bodies of water in southeastern Canada.

Figure 3 shows temperatures recorded since 1840 in Montreal. The coldest year recorded was 1875 and the warmest, 1953. Extreme fluctuations are evident over brief periods - almost 4°C between 1875 and 1877, for example.

A comparison of thermometric records for Montreal and Toronto (Figure 4) shows that temperature fluctuations were nearly parallel. Later, we will analyze these data statistically to show differences in range between the two series. The average difference between them, as far as can be determined on the basis of 10-year averages (Figure 5) from 1880 to the present, is about 2°C. Interestingly, this difference is due mainly to low winter temperatures in Montreal. There is not much difference in summer averages for the two cities (Figure 6). Apparently, in these two cities, weather conditions are similar in summer and different in winter. This is probably because heat retained by the Great Lakes in summer is released in winter thus moderating Toronto temperatures then, and because of latitudinal differences between Toronto and Montreal. Further interpretation will be possible once the barometric readings have been compiled and compared to the thermometric series.

The period 1860-1874 was an unusual one; temperature fluctuations between Montreal and Toronto show phase fluctuations, or are sometimes intermingled. This is probably the effect of changes in instrumentation (especially in Montreal), in the location of stations, or in the recording schedule. For example, six different recording stations can be identified in Montreal during this period.

A.I.+

391. **HILLAIRE-MARCEL, C., S. OCCHIETTI, and G. PRICHONNET. 1980. Historical, hydrological and physical evidence of changing climate in eastern Canada. In: Climatic Change in Canada. Edited by: C.R. Harington. Syllogeus 26:61-72.**

Within their research program of using "historical data to trace the variations in climate which have occurred in eastern Canada since colonization" the authors are conducting three projects.

(1) Historical study of variations in climate in eastern Canada: Inventory of documents.

Newpapers and periodicals, and reports of port and maritime activity are being used to reconstruct these climatic variations.

(2) Study of variations in the flow of rivers and in the level of some of the lakes of southern Quebec: Ice jams, ice break ups, floods, movement of sediment.

Various documents will provide the data, which will be graphically and statistically analyzed.

(3) Physical data on the climate and climatic cycles in eastern Canada during historical times.

Physical data from several selected sites will be correlated with a view to reveal fluctuation tendencies and note future cycles.

A.B.S.

392. **HILLAIRE-MARCEL, C., and P. PAGE. 1981. Paléotémperatures isotopiques du Lac Glaciaire de Deschaillons. In: Quaternary Paleoclimate. Edited by: W.C. Mahaney. Geo Abstracts, Norwich. pp. 273-298.**

Lake Deschaillons varves (beginning of Guildwood Stadial, Wisconsin) contain calcareous concretions which, according to their isotopic composition (^{18}O, ^{13}C, ^{14}C), precipitated during two different periods. Some concretions formed during the period of sedimentation, whilst others developed after the ice retreated from the St. Lawrence Lowlands (i.e. during Champlain Sea and Lake Lampsilis times). The ^{13}C content of the concretions indicates a mainly biological origin for carbon which, in turn, suggests the influence of bacterial activity in $CaCO_3$ precipitation. With careful isotopic controls, it is possible to give some credence to the ^{14}C age of the underlying St. Pierre peat beds. The observed changes in the $^{18}O/^{16}O$ ratio of the synsedimentary concretions have been associated with (1) a decrease of lake water temperature and (2) a progressive depletion of lake water in heavy isotopes. The latter factor reflects "lighter precipitations" with the cooling climate which preceded the ice invasion. The change in the $^{18}O/^{16}O$ ratio of the lake water corresponds to a decrease of the annual mean temperature of the St. Lawrence Lowlands, from c. +3°C to -5°C, using Dansgaard's relation between ^{18}O in precipitations and temperature.

A.A.

393. HILLAIRE-MARCEL, C., J.M. SOUCY, and A. CAILLEUX. 1979. Analyse isotopique de concrétions sous-glaciaires de l'inlandsis laurentidien et teneur en oxygène 18 de la glace. Canadian Journal of Earth Sciences 16(7):1494-1498.

Calcareous concretions occurring on Grenvillian gneiss have been discovered north of Hull, Quebec. Their structure and isotopic composition (δ PDB^{18}O $\simeq$ $-26^{0}/_{00}$; δ PDB^{13}C $\simeq$ $0^{0}/_{00}$; ^{14}C age >35000 BP) indicate subglacial conditions of precipitation. It is concluded that they were deposited at the base of the Laurentide ice sheet. Assuming equilibrium conditions with the subglacial film of water during precipitation of calcite, it is possible to define a -27.5 to $-31.8^{0}/_{00}$ (vs. "standard mean ocean water" (SMOW)) range for the oxygen-18 content of the ice.

A.A.

394. HILLS, L.V., and E.V. SANGSTER. 1980. A review of paleobotanical studies dealing with the last 20,000 years; Alaska, Canada and Greenland. In: Climatic Change in Canada. Edited by: C.R. Harington. Syllogeus 26:73-224.

This paper provides a resumé of published paleobotanical data from Alaska, Canada, and Greenland. Articles are first listed according to site location (Figures 1 to 5, Table 1), then a summary of each article is presented (Table 2).

A.B.S.

395. HOBSON, G.D., and J. TERASMAE. 1969. Pleistocene geology of the buried St. Davids Gorge, Niagara Falls, Ontario: geophysical and palynological studies. Geological Survey of Canada Paper 68-67:1-16.

No fossiliferous beds were found in the boreholes between St. Davids and Lake Ontario below the Niagara escarpment. In the St. Davids Gorge, however, borehole 5 revealed the presence of pollen and plant macrofossils in silt, clay and sand at a depth of 106-183 feet from surface. These beds are both overlain and underlain by glacial deposits. Wood from the 150-foot level was dated at 22,800 ± 450 years before present (GSC-816). Pollen assemblages in samples taken from the 80-foot sequence of nonglacial beds were dominated by spruce[1] and pine[2] with small numbers of fir[3], birch[4] and several different types of non-tree pollen[5]. Spores and ferns, fungi, and *Selaginella* were found in some samples and pre-Pleistocene spores were present frequently. Moss leaves, fragments of bark, leaf cuticle and conifer needles, and twigs indicate presence of local vegetation. Cold climatic conditions are inferred from the palynological evidence and a late mid-Wisconsin age has been assigned to the nonglacial beds. The St. Davids Gorge was cut either during the last interglacial (Sangamon) interval, or earlier.

pA.A.

396. HODGSON, D.A. 1978. Absence of late Quaternary glacial features on the Ringnes and adjacent islands, Arctic Archipelago. Geological Society of America, Abstracts with Programs 10(7):422.

No evidence of Late Wisconsinan glacial or fluvio-glacial erosion or deposition has been found on the essentially fluvial and marine landscape of Amund Ringnes, Cornwall, Ellef

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[1] (*Picea*)
[2] (*Pinus banksiana*)
[3] (*Abies*)
[4] (*Betula*)
[5] (including f. ex. *Artemisia, Ambrosia*, and Chenopodiaceae).

Ringnes, Graham or King Christian Islands. Dominant materials are weathered bedrock overlain by marine sediments (beyond the range of standard ^{14}C dating) and by Holocene marine sediments. Beach gravels with 'old' shells occur above the Holocene marine limit. Weathered till covers <1% of the area; the uppermost of two tills on Table Island is overlain by marine sediments with 'old' shells.

The Holocene marine limit, at least 9000 ^{14}C years old, lies at ca. 110 m a.s.l. in the central and eastern islands named, sloping to ca. 50 m in the west. There are no erosional marine landforms at the elevation of the highest Holocene shells. Beach gravels underlying the offshore marine sediments indicate an early Holocene transgression. Gravel-filled forest fissures beneath the offshore marine beds occur at two locations. However shells immediately above the onlap facies, at elevations close to present sea level, are no older than the highest Holocene surface samples.

Obviously, the islands had no warm-based Late Wisconsinan ice cover, and marginal meltwater features expected from cold-based ice are entirely lacking. Furthermore, Holocene uplift is not explained by the influence of distant ice caps and ice sheets, using current geophysical theory. The Ringnes Islands are 500 km from the nearest point of Greenland, and 300 km from the present day major Ellesmere ice caps, and at least 400 km north of the Late Wisconsinan Laurentide margin. It is suggested that Holocene uplift resulted from disappearance or contraction of ice caps on uplands bordering Norwegian Bay from Bathurst Island through Devon and Ellesmere Islands to Axel Heiberg Island, rather than from the influence of the more intensive Innuitian Ice Sheet.

A.A.

397. HOELLER, A.E. 1982. The role of environmental and historical evidence in climate reconstruction: a preliminary review and appraisal. Canadian Climate Centre, Downsview, Report No. 82-3:1-113.

This report presents an initial review and appraisal of some of the sources of proxy data that can provide a valuable contribution toward reconstruction of the climates of the past 10,000 years, and which may be particularly applicable to Canadian climate reconstruction. The proxy data sources explored are tree-rings, ice cores, sea cores, pollen, paleosols, lake levels, the climatic evidence from human history retained in historical documents and archeology. In addition to the above, a brief consideration of the C-14 dating technique and its alternatives is included. A bibliography accompanies each section of the review, which in conjunction with the text, provides an overview of paleoclimatology and its techniques, as well as sufficient resources for more in-depth reading.

pA.I.

398. HOFFMANN, R.S. 1980. Of mice and men: Beringian dispersal and the ice-free corridor. Canadian Journal of Anthropology 1(1):51-52.

By analogy to other mammalian dispersers of the late Pleistocene, I venture to predict that humans first crossed eastward across the Bering land bridge in the early Würm-Wisconsin (70-50 thousand yrs. BP), as cold-steppe predators into the interior of the Alaska-Yukon ice-free refugium, as littoral scavengers along the southern margin of the land bridge, or both. It seems very likely that during the Early Wisconsin a large glacial ice barrier resulted from coalescence of Cordilleran and Laurentide ice, but that deglaciation was sufficient during the Middle Wisconsin (35-25 thousand yrs. BP) to form an "ice-free corridor" and probably drowned the Bering land bridge for a time (Hopkins, 1973). During this time, humans dispersed southward out of the Alaska-Yukon refugium into mid-latitude North America and probably beyond. After 25 thousand yrs. BP, a second episode of glacial coalescence, perhaps 10,000 years in length, prevented dispersal southward out of the Beringian region (Rutter, 1980). Finally, with the climatic change that brought the Wisconsin to an end about 13,000 yrs. BP, the ice-free corridor opened again, permitting a second wave of human immigrants to spread southward throughout North and South America.

Excerpt

399. HOLLOWAY, R.G. 1978. Absolute pollen analysis of Lake Wabamun, Alberta, Canada. American Quaternary Association, National Conference, Abstracts 5:213.

A 16 m core was obtained from stratified sediments in Lake Wabamun, Alberta, revealing a 16000 year history in this region. Absolute pollen frequencies were calculated and indicated a fairly stable vegetational and, by implication, climatic history for this time period.

Geologic evidence from central Alberta suggest that Lake Wabamun was not covered by the Laurentide Ice Sheet 16000 years ago but instead was located between two lobes of this Late Wisconsin maximum glacial advance. Pollen data reveal that 16000 years ago the Lake Wabamun area supported a Tundra type vegetation similar to what is presently found in the Arctic Archipelago. Other data suggest that the increase in the pollen influx (ca. 12000 BP) resulted from the major retreat of the ice sheet and colonization by various plant communities. By 11000 BP the early colonization was followed by a Boreal Forest type vegetation assemblage which remained until severely reduced by a short, but destructive deposition of volcanic ash, preceeding the re-establishment of the forest. A warming trend followed which culminated in the Hypsithermal Period. This warming trend was characterized in the pollen record by fluxuating increases and decreases in the arboreal component which suggest the presence of a forest-grassland ecotone. The Hypsithermal represented the largest expansion of prairie elements into central Alberta. The climatic conditions present during the Hypsithermal affected the pollen preservation and resulted in such a low fossil pollen yield that no interpretation for this period can be offered at this time. Following the Hypsithermal, conditions became cooler and moister allowing for the re-establishment of a Boreal Forest. At approximately 2000 BP the pollen concentration begins to decrease, and is interpreted to represent a change to a more Parkland-like or ecotone type vegetation. A sharp decrease in the pollen influx is also noted at ca. 1000 BP. It is possible that the decrease noted in both the pollen influx and the organic content represent a slight change in the regional vegetation. On the other hand, it may also represent evidence of vegetational modification by early human populations in this area.

A.A.

400. HOLLOWAY, R.G., V.M. BRYANT, Jr., and S. VALASTRO. 1981. A 16,000 year pollen record from Lake Wabamun, Alberta, Canada. Palynology 5:195-208.

Analysis of fossil pollen from Lake Wabamun sediments record a Late Quaternary vegetational record for the last 16,000 years and indicates that the area between the Laurentide and Cordilleran ice centers was ice-free since at least 16,000 years B.P. Pollen influx and pollen percentage data indicate a vegetational sequence beginning with a tundra vegetation from 16,000-11,750 years ago. By 11,750 years B.P., birch and alder colonized the area but was soon followed by a cold-climate type coniferous forest composed primarily of spruce with some elements of birch and poplar. A warming trend begins around 9250 years B.P. which culminates in the Hypsithermal. However, pollen preservation is poor during this portion of the record for direct vegetational reconstruction. Immediately following the Hypsithermal, a spruce-poplar vegetational association was present that was similar to some present boreal forest areas in northern Alberta. Around 2000 years B.P. the pollen influx values decline and suggest a shift to a poplar-dominated vegetation with spruce still abundant. This vegetation assemblage seems to have marked the beginning of the present aspen grove and parkland vegetation found in central Alberta today.

A.A.

401. HOOKE, R.L., E.C. ALEXANDER, Jr., and R.J. GUSTAFSON. 1980. Temperature profiles in the Barnes Ice Cap, Baffin Island, Canada, and heat flux from the subglacial terrane. Canadian Journal of Earth Sciences 17(9):1174-1188.

Temperature measurements were made in seven boreholes, ranging in depth from 50-276 m, in the Barnes Ice Cap. Hole B4, D4, and T0975 are approximately 1 km from the margin and an average of 8 km apart. Holes T091, T081, T061, and T020 lie along a 10.2 km flow line passing through T0975. Temperature profiles are convex upward in all holes except T020, reflecting the combined effects of longitudinal and upward vertical advection, and frictional heating. The profile in T020 is concave near the bottom of the hole, as a result of downward vertical advection, but convex above mid-depth, owing to a 2.5°C cooling of the near-surface ice in the early 1940s.

Modeling, using a finite difference scheme, suggests that the profiles are in equilibrium with slightly lower vertical velocities and longitudinal advection rates than exist at present, and that temperatures at the glacier surface have increased 0.1-1.5°C over the last few decades. The modeling further suggests that the heat flux from the subglacial terrane beneath most holes is 0.5-0.8 heat-flow units (HFU), which is somewhat lower than the average geothermal flux on the Canadian Shield. The heat flux seems to decrease down-glacier along the flow line through T0975, apparently reflecting climatic warming of about 2° at the end of the Little Ice Age. In contrast, the heat flux appears to increase southeastward from the flow line, reaching an anomalously high value of about 1.9 HFU at B4. This trend is unexplained.

Measurements of U, Th, and K in rock samples collected near the margin suggest heat production rates of about 5 heat-generation units (HGU), which is slightly higher than previous measurements on Baffin Island.

A.A.

402. HOPKINS, D.M. 1972. The paleogeography and climatic history of Beringia during late Cenozoic time. Inter-Nord 12:121-150.

Beringia (Alaska[1], northeastern Siberia, and the intervening continental shelves) has played a strategic role in the evolution of northern biota during late Cenozoic time, because of its position athwart restrictions in both intercontinental and interhemispheric dispersal routes. Exposures of the extensive shelf areas during marine regressions and changes in water circulation across the shelf during transgressions have had dramatic effects upon the climate. A dichotomy between a maritime climate in the generally mountainous southern coastal fringe and a more continental climate in uplands and lowlands further north has been an enduring feature of Beringian history. But the continentality of the central and northern regions was greatly enhanced during intervals of low sea level, when Beringia was a single, broad landmass and when extensive ice caps in the coastal mountains blocked northward penetration of moist air masses. It is clear that the North Pacific Ocean and southern Bering Sea have been the persistent sources of moisture and that the Arctic Ocean, ice-free or not, failed to contribute importantly to precipitation in Beringia.

A temperate climate prevailed in Beringia until shortly before the beginning of the Pleistocene Epoch, although glaciation began in the mountains of Alaska and probably in the mountains of Kamchatka and the Koryak region some 10 m.y. ago. The effects of severe frost action are first recorded in lowland areas about 2.0 m.y. ago, and the earliest evidence of permafrost is in deposits about 1.0 ± 0.5 m.y. old. Forest vegetation probably covered most of Beringia throughout the Pliocene Epoch; the tundra biome did not appear until near the beginning of the Pleistocene Epoch. The Arctic Ocean seems to have been either ice free or only seasonally icebound until well into Pleistocene time.

A series of progressively "colder" interglacial marine transgressions culminated in the middle Pleistocene Kotzebuan Transgression, during which cold, Arctic water flowed southward through the Bering Strait. Glaciers may have been present in the mountains of Chukotka and northern Alaska, and this may have resulted in local changes in albedo sufficient to trigger subsequent growth of continental ice caps during the penultimate (Illinoian or Salle) glaciation. Paleoclimatic data are inadequate for a detailed reconstruction of the climate during the penultimate glaciation, but of the several episodes recorded in Beringia, this was the most extensive.

The last (Sangamon or Eem) interglaciation was a time of relatively mild climate during which spruce forest extended well north and west of the modern forest limit in Alaska, and birch woodlands became established in sheltered valleys in Chukotka. The distribution of fossil marine mollusks indicates that warm Pacific water entered southwestern Bering Sea and meandered northward to Bering Strait and thence into the Chukchi Sea. Winter sea ice probably was restricted to regions north of the strait. The last interglaciation was punctuated, however, by a marine regression during which the climate temporarily became more severe.

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[1] Ed note: Western Yukon should be included.

Climatic fluctuations during the early part of the last (Wisconsin or Warthe) glaciation are poorly understood, but this cold cycle culminated in a period of extremely severe climate between 13,000 and 20,000 years ago. Glaciers covered the mountain ranges bordering the Pacific Ocean and southwestern Bering Sea, as well as large areas in the Brooks Range and the mountains of Chukotka. The climate of central and northern Beringia was strongly continental and very dry. Persistent barometric highs over the polar sea ice resulted in strong northeast winds in regions north of the Arctic Circle, and the ice fields of southern Alaska produced strong and persistent katabatic southwest winds in central Alaska. Tundra-steppe clothed most of unglaciated Beringia. Forest biota persisted only in a few unglaciated enclaves in Kamchatka and in a refugium on the continental shelf somewhere near the modern Yukon River Delta.

There is no clear record in Beringia of the dramatic climatic oscillations recorded in temperate latitudes between 13,000 and 10,000 years ago. Bering Strait was reopened as a sinuous, shallow seaway, when sea level rose to -38 meters about 13,000 or 14,000 years ago, and this brought a milder climate to western Alaska and probably also to Chukotka. However, the climate of central Alaska remained cold and dry. Evidence for strong northeast winds on the Pribilof Islands suggests that the persistent barometric high was now located over pack ice on the continental shelf of the Chukchi Sea.

A sharp vegetation change records a rapid warming throughout Beringia about 10,000 years ago. In most parts of Beringia, the Holocene warming seems to have peaked in a minor thermal maximum about 5,000 years ago, but northwestern Alaska has experienced two climatic optima-one within the interval 10,000 to 8,000 years ago and another during the last three decades-during which forest biota expanded to their furthest limits. These expansions of forest biota in northwestern Alaska seem to have taken place during intervals when summer weather was clear and warm, but the cause of this local summer warming remains obscure.

A.A.

403. HORBERG, L., and R.A. ROBIE. 1955. Postglacial volcanic ash in the Rocky Mountain Piedmont, Montana and Alberta. Geological Society of America Bulletin 66:949-956.

A volcanic ash layer, which occurs in postglacial alluvium and colluvium at several localities in southern Alberta and northwestern Montana, is named Galata ash. The stratigraphic relations and physical properties of the ash indicate a single episode of volcanic activity and possible correlation with an ash layer in southwestern Glacier Park assigned on the basis of pollen analyses to the postglacial Xerothermic period.

A.A.

404. HORN, D.R. 1963. Marine geology, Peary Channel, District of Franklin. Geological Survey of Canada Paper 63-11:1-33.

Reports the 1961 survey of Hasseland Massey Sounds and Peary and Sverdrup Channels in a 10,000 sq. mi. area in the Queen Elizabeth Islands, east of that reported by Marlowe and Vilks, q.v. Main features of sea-floor morphology are noted and their significance indicated; sources and characteristics of the fluvial and recent marine sediments, some of them unique to arctic regions, are discussed. Most of the 44 cores taken offshore consist of a surface layer of dark brown silty clay underlain by dark gray to black interbedded silt and clay; it averages 34 cm. thick. The second layer at less than 190 m. depth has oxidized soil, coarse sands at 200 m., grading downward into coarse silt at about 400 m., and below that, clay. Environmental conditions during deposition of the second layer were unlike those today; the water was cooler, and faunal content is less in that part of the offshore cores. Data on inshore and offshore core samples are tabulated. Submarine topography is interpreted on a map 1 in.: 10 mi. A longitudinal and four transverse profiles are included.

A.B.

405. **HOWDEN, H.F. 1975. Late Quaternary history of some maritime insects. In: Environmental Change in the Maritimes. Edited by: J.G. Ogden, III and M.J. Harvey. Proceedings of the Nova Scotian Institute of Science 27(Supplement 3):61-66.**

Discusses past insect distributions, mostly beetles. The results seem to indicate, at least for the eastern maritime beetles associated with deciduous forests, that they survived glaciation in southeastern North America, and reinvaded the maritime regions gradually during the last 10,000 years.

L.G.

406. **HUFTY, A. 1981. Fluctuations climatiques récentes au Québec. Géographie physique et Quaternaire 35(1):49-55.**

The problem is approached in three separate, but complementary manners centring on a study of temperature regimes in Québec. These regimes indicate irregular fluctuations around a slight tendency upward, that is most evident in the St. Lawrence Lowlands and that peaks around 1950. These variations are in part global and a number of authors, in particular Budyko and Bryson, have tried to account for them by means of energy budget models that indicate the climatic consequences of changes in the amount of dust and CO_2 present in the atmosphere, as well as of volcanic eruptions. These climatic theories are becoming better and better known, even outside the scientific community, and there is some indication that the perception of climatic change has increased even more than climate itself.

A.A.

407. **HUGHES, O.L., C.R. HARINGTON, J.A. JANSSENS, J.V. MATTHEWS, Jr., R.E. MORLAN, N.W. RUTTER, and C.E. SCHWEGER. 1981. Upper Pleistocene stratigraphy, paleoecology, and archaeology of the northern Yukon interior, eastern Beringia. 1. Bonnet Plume Basin. Arctic 34(4):329-365.**

New stratigraphic and chronometric data show that Bonnet Plume Basin, in northeastern Yukon Territory, was glaciated in late Wisconsinan time rather than during an earlier advance of Laurentide ice. This conclusion has important ramifications not only for the interpretation of all-time glacial limits farther north along the Richardson Mountains but also for non-glaciated basins in the Porcupine drainage to the northwest. The late Wisconsinan glacial episode in Bonnet Plume Basin is here named the Hungry Creek advance after the principal Quaternary section in the basin. Sediments beneath the till at Hungry Creek have produced well-preserved pollen, plant macrofossils, insects, and a few vertebrate remains. The plant and invertebrate fossils provide a detailed, if temporally restricted, record of a portion of the mid-Wisconsinan interstadial, while the vertebrate fossils include the oldest Yukon specimen of the Yukon wild ass. Some of the mid-Wisconsinan sediments have also yielded distinctive chert flakes that represent either a previously unreported product of natural fracturing or a by-product of stone tool manufacture by human residents of Bonnet Plume Basin.

In addition to presenting new data on these diverse but interrelated topics, this paper serves as an introduction to a series of reports that will treat in turn the Upper Pleistocene record of Bluefish, Old Crow, and Bell basins, respectively.

A.A.

408. HURT, W.R. 1966. The Altithermal and the prehistory of the Northern Plains. Quaternaria 8(15):101-114.

To explain the relative difficulty of finding sites of human occupancy in the Northern Plains during the Altithermal (c. 5000-2500 B.C.) archaelogists have postulated that the climate, as in the Grand Basin, was so arid that man and the grazing animals emigrated to better watered areas. Tables of known archaeological sites on the Northern Plains show that the duration of sparse population lasted from about 5000 to 3600 B.C., that is for most of the Altithermal. Because of the lack of research in the Northern Plains there is little direct evidence concerning the specific features of climate of the Altithermal. However, archaeological, geological and palynological sites prove that this period of sparse population is associated with the postglacial thermal maximum. One can postulate that a similar climate existed in the most central area. Certain parts of the Northern Plains, because of their physical features, received relatively more precipitation than the area as a whole. Therefore, during the severest Altithermal droughts man may have moved to the more favourable habitats.

G.A.

409. HYVÄRINEN, H., and J.C. RITCHIE. 1975. Pollen stratigraphy of Mackenzie pingo sediments, N.W.T., Canada. Arctic and Alpine Research 7(3):261-272.

Two eroded pingos, of the closed system type abundant in the uplands east of the Mackenzie Delta, yielded sections of pond sediment of Holocene age. Pollen stratigraphy of both sections confirms the general sequence established earlier by Ritchie (1972): Zone I dominated by *Betula glandulosa* associated with low frequencies of *Salix* and *Artemisia*; Zone II dominated by *Picea* (20 to 40%) and *Betula* (50%) and Zone III showing roughly equal representation of *Alnus*, *Betula*, and *Picea*. Zone IV is represented only at the Hendrickson Island site and is distinguished from Zone III by the increases in *Betula*, ericads, and sedges, and a decline of *Alnus*. Radiocarbon analyses suggest that the growth of the two pingos was initiated at least 2,500 years ago. The Zone I assemblage, which has been widely reported in the northwest Arctic-Subarctic of North America was replaced by Zone II about 9,000 BP; at Eskimo Lakes it represents a migration of spruce into birch-dominated tundra, but it is unlikely that spruce actually grew at Hendrickson Island. The Zone III to IV changes confirm the proposition (Ritchie and Hare, 1972) that the tree line has retreated to its present position during the postglacial.

A.A.

410. The Ice-free Corridor and Peopling the New World. Edited by: N.W. Rutter and C.E. Schweger. Canadian Journal of Anthropology 1(1):1-139. 1980.

Proceedings of the 5th Biennial Meeting of the American Quaternary Association, Sept. 2-4, 1978 in Edmonton. Articles are annotated individually.

A.B.S.

411. INGRAM, M.J., and D.J. UNDERHILL. 1979. The use of documentary sources for the study of past climates. International Conference on Climate and History, University of East Anglia, Norwich, July 8-14. Review Papers, pp. 59-90.

Documentary evidence is an important source of detailed information on past climates, particularly for the period from about 1100 A.D. to the beginnings of the era of instrumental meteorology. This paper is concerned with the study and climatic interpretation of this evidence. It comprises four sections. The first provides a survey of the available sources, offering some insights into the historical milieux which produced them and indicating in very general terms the kinds of information they contain. There are, however, many pitfalls involved in using historical records, and in the second section we discuss the most basic of them, the problems involved in assessing the reliability of sources as records of events. The third section deals with the more difficult problems of source interpretation and analysis, some attention being given to the use of content of the material to produce climatologically valuable data. In turn we consider the analysis of early instrumental observations; the construction of meteorological series from the relatively few types of documentary data which provide continuous series of more or less homogeneous information; and the analysis of fragmentary and nonhomogeneous series using indexation procedures and spatial mapping techniques (the latter being used to make possible the analysis of qualitative material in terms of atmospheric circulation patterns).

A.A.

412. IRVING, W.N., and C.R. HARINGTON. 1973. Upper Pleistocene radio-carbon dated artefacts from the northern Yukon. Science 179(4071):335-340.

In 1966 a caribou bone fleshing tool was collected with two mammoth bone artefacts and a rich assemblage of Pleistocene fossils at a site in the Old Crow Basin, Yukon Territory. The fleshing tool was radiocarbon dated at 27,000 (+ 3000/- 2000) years B.P. (GX-1640), indicating that people lived in this part of the Beringian refugium before the peak of the last (Wisconsin) glaciation.

In addition to plant, mollusc, fish and bird remains, 18 species of mammals are recorded from the site, 9 of which are extinct in the Yukon. Faunal remains consist of two components: (1) a cold-adapted component including a number of species derived from Eurasia (e.g. woolly mammoth, caribou, bison and arctic fox); and (2) a warm-adapted component derived from southern North America (e.g. camel, giant beaver, American mastodon). It is postulated that the two components are approximately of similar age, suggesting a period of transition from a warm (Sangamon interglacial?) climate to a cooler (Wisconsin glacial) one, in which extensive loess-steppe grasslands occurred.

C.R.H.

413. IVES, J.D. 1958-59. Glacial drainage channels as indicators of late-glacial conditions in Labrador-Ungava: a discussion. Cahiers de Géographie de Québec 3(5):57-72.

The majority of glacial drainage channels in the vicinity of Schefferville were formed in sub-lateral or sub-glacial positions. The study of these channels can lead to an evaluation of the conditions prevailing during the final phase of wastage of the ice mass. The ice, at least during the final stages of wastage, was at the pressure melting point, the snowline was well above the land surface and large volumes of melt-water formed annually. The author concludes that the mean annual temperature (and particularly the summer temperature) during the period of final melting of the ice sheet on the "lake plateau" was comparable with, if not, higher, than that of today; a conclusion hardly compatible with botanists' views. It is suggested that temperature was warmer than the vegetation indicates, there being a lag between rate of climatic amelioration and development of vegetation.

L.G.

414. IVES, J.D. 1962. Indications of recent extensive glacierization in north central Baffin Island, N.W.T. Journal of Glaciology 4(32):197-205.

Studies of the geomorphology and rock lichen development north of the Barnes Ice Cap prompt the conclusion that 70 per cent of this extensive, interior region was covered by permanent ice some 300 to 400 yr. ago. Contemporaneously the northern Barnes Ice Cap was significantly larger than today; it dammed up a lake in the upper Isortoq valley, over 80 km. long and up to 300 m deep. Excluding the ice cap, less than 2 per cent of the area is glacierized today; this represents a dramatic reduction in surface area of the former ice cover. Similarly, significant recession of the ice cap implies that glaciers of the "Baffin type" are in a less healthy budgetary state than hitherto has been assumed.

Proof of former extensive ice cover rests largely upon restricted rock lichen development. When sufficient time has elapsed for complete colonization, few indications of the former existence of an ice cover will remain. This type of glacierization may have affected large areas in the high Arctic. Absence of evidence of glaciation, therefore, cannot be relied upon to delimit nunatak areas (plant refugia) during the last glaciation.

A.A.

415. **IVES, J.D. 1978. The maximum extent of the Laurentide Ice Sheet along the east coast of North America during the last glaciation. Arctic 31:24-53.**

During the last hundred years, two widely opposing views of the maximum extent of the Laurentide Ice Sheet have prevailed at different times. Between 1860 and 1940, it was assumed that ice extent along the eastern seaboard was limited and that ice-free areas persisted during the Maximum of the Last Glaciation. After 1940, this interpretation was replaced by one contending that all high coastal mountains were inundated. This view, proposed by the late R.F. Flint, was widely accepted as fact until the last few years. This paper reviews the opposing interpretations and analyses the frequently equivocal field evidence and the developments of thought responsible for them. On the basis of field work carried out over the last twenty years, it is suggested that the earlier viewpoint was the more accurate. A map is presented of the author's conclusions regarding maximum ice limits.

A.A.

416. **IVES, J.D., J.T. ANDREWS, and R.G. BARRY. 1975. Growth and decay of the Laurentide Ice Sheet and comparisons with Fenno-Scandinavia. Naturwissenschaften 62(3):118-125.**

The history of thought relating to the initiation, growth, and decay of the Laurentide Ice Sheet is traced and the traditional hypothesis of "highland origin and windward growth" is re-examined. Extensive field data from Labrador-Ungava and Baffin Island are reviewed in a climatological context. An alternative conceptual model of "instantaneous glacierization", based on a late Neoglacial extensive snow cover over much of the eastern Canadian Arctic and Subarctic, is proposed. Comparisons with Fenno-Scandinavia are made in the light of this new model.

A.A.

417. **IVES, J.D., H. NICHOLS, and S.K. SHORT. 1976. Glacial history and paleoecology of northeastern Nouveau-Québec and northern Labrador. Arctic 29(1):48-52.**

Lake sediment cores were taken from ten lakes ranging from Boundary Lake, north of Schefferville, to Miriam Lake in the Four Peaks area of the Torngat Mountains. ... Initial field examination of the Torngat Mountain and George River basin cores revealed that the topmost sequence was consistently a layer of coarse sand overlying more organic sediments. this indicates a recent environmental disturbance involving accelerated soil erosion. ...

[A study of three weathering zones, Torngat, Koroksoak and Saglek, in the southern Torngat Mountains was also conducted.] ... a tentative correlation is made between Baffin Island Zone III, Labrador Saglek Zone, and the maximum extent of Wisconsin ice in the eastern Canadian Arctic. The Koroksoak Zone bears numerous signs of former glacial activity and presumably can be related to a pre-Wisconsin glaciation, or glaciations. ...

Extracts$^+$

418. JACKSON, L.E., Jr. 1979. New evidence for the existence of an ice free corridor in the Rocky Mountain Foothills near Calgary, Alberta, during late Wisconsinan time. Geological Survey of Canada Paper 79-1A:107-111.

A 12 m core from a bog near Turner Valley, Alberta, has yielded ^{14}C dates of 18 400 ± 380 years and 18 500 ± 1090 years B.P. from near its bottom. These dates provide minimum ages for the end of the last glaciation during which Rocky Mountain provenance ice advanced east of the mountain front and covered much of the Foothills. A buried soil horizon near southeast Calgary lies between the youngest glacial till and glaciolacustrine silts. The stratigraphic position of the soil horizon precludes an advance of the Laurentide Ice Sheet into the Foothills since at least the end of the early Wisconsinan stage.

A.A.

419. JACKSON, L.E., Jr. 1980. Quaternary stratigraphy and history of the Alberta portion of the Kananaskis Lakes Map Area (82-J) and its implications for the existence of an ice-free corridor during Wisconsinan time. Canadian Journal of Anthropology 1(1):9-10.

In conclusion, four glaciations are recorded in the Alberta portion of the Kananaskis Lakes sheet. The third glaciation of at least Early Wisconsinan age involved the last coalescence of Rocky Mountain and Laurentide ice in this area. During the Late Wisconsinan, valley glaciers advanced only as far as the mountain front, whereas the Laurentide ice sheet never advanced above about 1036 m elevation east of the Kananaskis Lakes Sheet.

Excerpt

420. JACOBS, J.D., and C.Y.Y. LEUNG. 1981. Paleoclimatic implications of topoclimatic diversity in Arctic Canada. In: Quaternary Paleoclimate. Edited by: W.C. Mahaney. Geo Abstracts, Norwich. pp. 63-75.

It has often been observed that in the Arctic, particularly in areas of varied relief, a wide range of microclimatic conditions may be encountered over short distances and under the same regional climatic influences. Such topoclimatic diversity is most evident in the spatial patterns and relative and absolute abundances of vegetation.

Field investigations in coastal areas of moderate relief (0 to 600 m.a.s.l.) in Baffin Island have provided the empirical basis for modeling and mapping topoclimates in relative terms. LANDSAT imagery and aerial photographs permit extension of the method to other areas. The topoclimate mapping method uses theoretical solar radiation on slopes and sheltering effects upon prevailing winds to identify areas of relatively favorable microclimates. Good spatial correspondence is found between such maps and vegetation maps derived from LANDSAT imagery.

The high degree of spatial variability in microclimate and plant habitat is paralleled by a large temporal variability in regional climate. Associated with the short-term climatic fluctuations are occasional extreme weather events which can have a pronounced impact upon the landscape.

Taken together, these observations point to the need for caution in the interpretation of proxy climatic data from widely scattered sites. The reconstruction of past climates and landscapes should proceed on the assumption that the degree of spatial variety observed in the present existed also in the past.

A.A.

421. **JACOBS, J.D., and J.P. NEWELL. 1979. Recent-year-to-year variations in seasonal temperatures and sea ice conditions in the eastern Canadian Arctic. Arctic 32(4):345-354.**

Mean summer and winter temperatures for the 1957-1978 period have been analyzed for four eastern arctic stations. Standard deviations on the order of 3°C in winter and 1°C in summer indicate the magnitude of the interannual variations, and these departures are found to be synchronous over the region. Several indices of sea ice severity also show significant year-to-year variations, but these are not spatially coherent. Relationships between climatic parameters and sea ice are examined in order to explain these differences.

A.A.

422. **JACOBS, J.D., and G. SABO,III. 1978. Environments and adaptations of the Thule Culture on the Davis Strait coast of Baffin Island. Arctic and Alpine Research 10(3):595-615.**

The eastern coast of Baffin Island is a climatically severe, topographically complex arctic region. Archaeological and historical evidence show that the area was occupied over part, if not all, of the last two millenia by small Eskimo populations. Investigations of the distribution and environments of dwelling sites along a portion of the Davis Strait coast indicate a pattern of site selection which provides the optimum local environment from a demonstrably wide range of alternatives. Site surveys give some indication of the degree of topoclimatic diversity which exists in the region. It is suggested that the observed patterns of site selection and utilization represent a particular local adaptation on the part of Thule culture inhabitants to this climatically stressful region.

A.A.

423. **JACOBY, G.C., and E.R. COOK. 1981. Past temperature variations inferred from a 400-year tree-ring chronology from Yukon Territory, Canada. Arctic and Alpine Research 13(4):409-418.**

A time series of ring-width indices from 27 cores of 13 white spruce trees (*Picea glauca*) from a site near the Dempster Highway, Yukon Territory (65°20'N, 138°20'W) shows growth response to summer temperatures and other climatic variables. Temperature information can be inferred for the last 400 years. The earliest part of the tree-ring curve shows effects of the "Little Ice Age", there is a warmer period centering around the late 1700s, and then a severe cooling trend toward the mid-1800s followed by the Northern Hemisphere warming. Since about 1950, there appears to be a trend toward cooler temperatures.

C.R.H.

424. **JACOBY, G.C., and L.D. ULAN. 1981. Review of dendroclimatology in the forest-tundra ecotone of Alaska and Canada. In: Climatic Change in Canada 2. Edited by: C.R. Harington. Syllogeus 33:97-128.**

In the high-latitude forest-tundra ecotone, temperature shifts are larger compared to lower latitudes, and climatically sensitive tree-ring series longer than 500 years can be developed. Long-term climatic data are scarce. This paper reviews recent dendroclimatological studies from the forest-tundra ecotone of Alaska and Canada.

In this region, the dating of tree-ring material is more difficult, and the climatic signal less obvious, than in southwestern United States. However, the potential is high for dendroclimatology and archaeology using ring widths and the newer method of x-ray densitometry.

Our studies indicate that both temperature and moisture information are recorded in the rings of subarctic trees, especially in summer. Effects of the Little Ice Age and recent Northern Hemisphere warming are shown in past tree growth at several sites. There are also significant differences in sub-arctic tree growth based on data from sites across North America. Efforts are continuing to develop a transect of dendroclimatological sites for the northern forest-tundra ecotone.

A.S.

425. JACOBY, G.C., and L.D. ULAN. 1982. Reconstruction of past ice conditions in a Hudson Bay estuary using tree rings. Nature 298(5875):637-639.

A tree-ring chronology is derived from annual ring-width measurements of 15 increment cores from 7 white spruce (*Picea glauca*) from flat, poorly-drained muskeg near Churchill, Manitoba. Ten of these cores extended back to 1686 or earlier. Calibration of climatic data derived from the tree rings with climatic data derived from historical documents (1741-1769 A.D.) for first complete freeze of the Churchill River estuary shows a high degree of correlation. Based on this evidence, the authors reconstruct a record of days of first complete freezing of the Churchill River estuary for 298 years (1680-1977). The reconstruction is verified by modern data (1967-1977). The authors believe that additional reconstruction of ice conditions over wide areas can be achieved using tree-ring information.

C.R.H.

426. JANKOVSKA, V., and L.C. BLISS. 1977. Palynological analysis of a peat from Truelove Lowland. In: Truelove Lowland Devon Island, Canada: A High Arctic Ecosystem. Edited by: L.C. Bliss. University of Alberta Press, Edmonton. pp. 139-142.

A basal peat cored to determine pollen and plant material content, had an age of 2,450 ± 90 years B.P. (Barr, 1971). Moss peat and identifiable moss leaves predominated throughout the profile. *Salix arctica* and Poaceae accounted for most pollen; the absolute amount throughout the profile was low. Comparing this profile with others from Axel Heiberg Island and Greenland, the slow accumulation of peat in Truelove Lowland indicates a cold, dry climate has prevailed for the past 1,000+ years.

A.B.S.

427. JANSON, E., and E. HALFERT. 1937. A pollen analysis of a bog in northern Ontario. Papers of the Michigan Academy of Science, Arts and Letters 22:95-98.

This study is concerned with a northern Ontario bog at about 46°-47°N. and 79°-80°W.

The plant list indicates the typical subboreal flora of the Canadian coniferous forest.

The presence of *Quercus* in the lower layers of the peat and its subsequent absence would indicate inception of the bog deposits during a warmer climate than now prevails in this area.

The decrease of *Pinus* and the increase of *Abies* and *Picea* may perhaps signify an increase in humidity.

A.S.

428. **JOHNSON, F., and G.M. RAUP. 1964. Geobotanical and archaeological reconnaissance. In: Investigation in Southwest Yukon. Phillips Academy, Robert S. Peabody Foundation for Archaeology, Andover, Massachusetts, Paper 6.6(1-2):3-198.**

Reconstructs regional cultural developments on the basis of changes in climate, biota and topography inferred from the stratigraphy of silt deposits. Hunters followed herds into the Kluane Lake grasslands after retreat of glaciers and persisted through the Hypsithermal period, the hunting techniques changing with the appearance of large game and increasing forestation at the close of that period. The slow forest advance is attributed to the extreme aridity of the Dezadeash-Shakwak region aggravated, earlier, by a Hypsithermal climate. Contemporary landforms, surficial deposits and vegetation are described, archeological finds noted and ethnographic data supplied on the Athapaskan Indian community at Burwash Landing.

A.B.

429. **JOHNSON, L.P.V. 1940. Relation of sunspot periodicity to precipitation, temperature and crop yields in Alberta and Saskatchewan. Canadian Journal of Research 18(3):79-81.**

Coefficients of correlation (r) were calculated for sunspot data as related to annual precipitation and to temperature data for Edmonton, Calgary, Medicine Hat, Swift Current, Battleford and Qu'Appelle; and as related to data on the yields of wheat, oats and barley in Alberta and Saskatchewan. In all cases, the correlation was negative but only in the cases of precipitation at Edmonton, Calgary and Battleford were the values significant. Data giving significant values of (r) are given graphical treatment. It was concluded that while the sunspot cycle probably bears some casual relation to precipitation and perhaps also to temperature and indirectly to crop yields, it, nevertheless does not provide a basis for long range weather forecasting owing to the confusing effects of other determining facts. The literature on sunspot periodicity in relation to terrestrial phenomena is reviewed briefly.

Thomas

430. **JOHNSON, R.G., and J.T. ANDREWS. 1979. Rapid ice-sheet growth and initiation of the last glaciation. Quaternary Research 12(1):119-134.**

Calculations based on temperature-corrected oxygen-isotope ratios from deep-sea cores yield a glacioeustatic sea-level fall in excess of 50 m during the first 10,000 yr of the last glaciation, and generally support the local regression of about 70 m inferred from tectonically rising New Guinea beaches. We propose that this rapid glacial buildup depended on high-latitude cooling, and large increases of high-latitude regional winter precipitation in the Laurentide and the Fennoscandian-Barents Sea areas, and that these factors were caused by a critical alternation of North Atlantic Drift currents and their associated subpolar atmospheric circulation. In support of this, faunal data from northeast North Atlantic deep-sea cores show that the glacial buildup was accompanied by a sudden loss of most of the North Atlantic Drift from the Greenland-Norwegian Sea, a factor favoring reduced heat input into the higher latitudes. Subpolar mollusk and foraminifera faunas from elevated marine deposits on the Baffin Island coast, and northwest North Atlantic core data suggest a continuation or an associated restoration of subpolar water west of Greenland as far north as Baffin Bay, a factor favoring precipitation in the northeast Canadian region. Heat transport and atmospheric circulation considerations suggest that the loss of the northeast North Atlantic Drift was itself a major instrument of high-latitude climate change, and probably marked the initiation of major new ice-sheet growth.

A.A.

431. JONES, V.K. 1974. Late neoglacial regimes of an inland cirque glacier and their paleoclimatic implications. In: Quaternary Environments: Proceedings of a Symposium. Edited by: W.C. Mahaney. York University, Toronto. Geographical Monographs No.5:293-294.

Cathedral Glacier, a compound sub-Polar cirque glacier at 59°20'N, is located in Atlin Provincial Park on the continental flank of the northern Boundary Range in northwestern British Columbia. Active ice fills a bifurcated upper basin near 7,000 feet and flows past the eastern side of a medial nunatak at 5,400 feet to a receding terminus at 5,200 feet. Seasonal névé-lines for 1971, 1972 and 1973 were at 5,700, 6,300 and 5,500 feet, respectively. An ice-cored terminal moraine at 4,800 feet, laid down about 1920, continues to advance slowly. This is overriding a stable moraine, dated lichenometrically as mid-19th century,at its base. These terminal moraines mark the maximum post-Wisconsinan extension of the glacier.

Comparison of post-1900 meteorological data from the continental interior with that of the maritime coastal (Juneau) area indicates relative fluctuations in temperature and precipitation over time. Such fluctuations over much longer time spans are also revealed by palynological investigations of post-Wisconsinan bogs in the Atlin area and glacio-climatic interpretations from the Juneau Icefield, directly south of the study area.

The pattern of recent climatic fluctuations is examined in relation to circum-Polar westerly circulation in the upper atmosphere and its interaction with the linear topography of the Alaska-Canada Boundary Range. Changes in atmospheric circulation appear to have a causal relation to varying glacio-climatic regimes described in this and coastal areas. Thus, they may provide a significant key to interpretation of earlier Quaternary climatic variations.

pA.A.

432. JORDAN, R. 1975. **Pollen diagrams from Hamilton Inlet, central Labrador, and their environmental implications for the northern Maritime Archaic. Arctic Anthropology 12(2):92-116.**

Palaeoenvironments in Hamilton Inlet, central Labrador, Canada and the environmental implications for the northern Maritime Archaic are discussed. In order to investigate palaeoenvironments, a series of five lake sediment cores was procured and analyzed for fossil pollen.

Glacial recession proceeded from east to west beginning c. 9000 B.P. along the present coastline. Western Lake Melville was ice-free c. 6500 B.P. and final wastage of the ice sheet culminated c. 5800 B.P. on the interior plateau. Five pollen zones are evident based on the relative frequency of arboreal pollen, reflecting the process of the Holocene revegetation. Inferred cover types were as follows: barren landscape, periglacial tundra, alder thicket, birch-fir woodland and spruce forest. Spruce immigrated between 5800 and 5200 years ago into central Labrador. Thereafter, only relatively minor fluctuations of the forest-tundra boundary are registered. These changes reflect a mild period between 6500 B.P. and 4000 B.P.

The Maritime Archaic were the first people to occupy central Labrador, spreading into this region c. 6000 to 5500 B.P. from the Strait of Belle Isle region with the establishment of forested conditions. Primary economic activity was oriented to the procurement of marine resources, including sea mammals. Interior resources may have been severely limited during the initial period of expansion. The Maritime Archaic disappears from the Labrador Coast about 3800 B.P. during a period of climatic deterioration, which may have influenced the distribution, abundance and availability of marine resources.

A.A.

433. JUNGERIUS, P.D. 1967. The influence of Pleistocene climatic changes on the development of the polygenetic pediments in the Cypress Hills area, Alberta. Geographical Bulletin 9(3):218-231.

The geomorphological history of the unglaciated pediments south of the Cypress Hills plateau is reflected in the materials covering their surface. Deposits and soils formed in an arid or semi-arid environment alternate with solifluction deposits and other periglacial features. The pediments are produced by a combination of pediplanation and cryoplanation.

A.A.

434. JUNGERIUS, P.D. 1969. Soil evidence of postglacial tree line fluctuations in the Cypress Hills area, Alberta, Canada. Arctic and Alpine Research 1(4):235-246.

Soil evidence in the Cypress Hills suggests that the tree line has advanced beyond its present position several times since the Wisconsin glaciation. The first and major of these events extended from about 4,500 to 3,600 years BP. The tree line fluctuations, which are presumably due to climatic changes, are recorded in polygenetic soil profiles on erosional sites, and in a sequence of buried soils on depositional sites.

A.A.

435. KALAS, L.L. 1975. Malacological evidence of interglacial environments at Toronto, Ontario, Canada: a quantitative approach. Quaternary Non-marine Paleoecology Conference, University of Waterloo, Waterloo, Ontario. Program and Abstracts.

Excavations in the western portion of the Don Valley Brickyard, Toronto, Ontario, have exposed remnants of a 6-m-thick fossiliferous gravelly-sandy layer of the Don Formation situated 12-18 m above the present Lake Ontario level. The layer rests on bedrock (Ordovician shale) and was formerly overlain by more than 30 m of complex sediments including till sheets of the last glaciation. The exposure was sampled for shelled invertebrates in 12 cm sample intervals. In each sample interval there were recognizable amounts of mollusc specimens making possible a construction of a malacological diagram for the entire section. Totally, more than 55 species of mollusc were recovered. The most diverse group were Sphaeriacean clams, Prosobranchia and Unionaceans. An interpretation of the paleoenvironments of the fossil assemblages was obtained using computer techniques based on detailed studies of the ecological requirements of these mollusc species in recent Canadian environments and taking into consideration functional ranges of the mollusc species within their total distributional patterns. Forty-three environmental parameters (physical, chemical, climatological and biological) were determined for each of the sample intervals. An evaluation of these parameters showed that the mollusc-bearing layer was deposited by a medium sized river much larger than the present Don River which drained into a nearby lake embayment. The relationship of climatic and slight isostatic oscillations, lateral shifting of the river mid-channel and strong fluctuations of the lake level made the depositional environment unsteady. Episodic shallowing is evident near the base and upper part of the bed sequence. All variations in environmental parameters during the period of bed deposition range well within the optimal interglacial conditions.

A.A.

436. KANUGA, K.K. 1979. History of weather and climate modification. International Conference on Climate and History. University of East Anglia, Norwich, July 8-14. Abstracts, pp. 31-32.

This paper brings together a 32-year history of man's deliberate weather and climate modification activities, based on the vast body of scientific knowledge and experience gained through a combination of laboratory, field and numerical experimentation, since the revolutionary dry-ice cloud seeding experiment conducted by Shaefer in 1946. The major aspects of the subject included are: (i) Artificial stimulation of precipitation, (ii) Dispersal of fog, (iii) Suppression of hail, (iv) Mitigation of lightning, and (v) Taming of severe storms.

A review has also been made of the inadvertent large-scale weather and climate modifications which have largely occurred in the last 200 years due to man's increasing activities in urbanisation, industrialisation and use of fossil fuels.

The possible legal, social, political, economic, agricultural and ecological ramifications of man's deliberate and inadvertent activities in modifying weather and climate have been discussed. The general public opinion on the subject is also debated.

A.A.

437. KARROW, P.F. 1963. Pleistocene geology of the Hamilton-Galt area. Ontario Department of Mines, Geological Report 16:1-68.

The Hamilton-Galt report-area, at the west end of Lake Ontario, straddles the Niagara Escarpment, and is underlain by rocks of Ordovician and Silurian age. Tills representing six ice advances have been identified; all are believed to be Wisconsinan, and mostly Late Wisconsinan, in age. From oldest to youngest, they are mapped as "lower beds", Canning Till, Catfish Creek drift (Tazewell?), Port Stanley drift (Cary), Wentworth Till (Port Huron), and Halton Till (Port Huron).

During and following these ice-advances, shore features and bottom sediments were left by the glacial lakes Whittlesey, Warren, Peel, and Iroquois. Lake Iroquois has been dated at about 12,000 years ago. Wentworth Till is the surface till over much of the Galt map-area and forms 200 drumlins and several end moraines. Sand and gravel are produced mainly from extensive outwash and spillway deposits and, in lesser amounts, from raised beaches, eskers, and kames.

[Fossils identified from the Lake Iroquois deposits indicate cold, shallow water conditions. Pollen in the Lake Ontario sediments indicates a warmer climate in the upper levels and a cold climate in the lower levels. A kettle bog near Crieff was studied and a pollen diagram constructed. The base of the bog was radiocarbon-dated at 11,950 ± 350 years and the diagram records that as time passed, the climate became warmer, and evergreens were replaced by deciduous trees.]

A.A.+

438. KARROW, P.F. 1976. The interglacial-glacial transition in the Toronto interglacial. Geological Society of America, Abstracts with Programs 8(6):946-947.

Changing climate and paleogeography during the time from the climatic optimum of an interglacial (Sangamonian?) to the first subsequent glaciation, are recorded by four formations in the Toronto area, Ontario.

The Don Formation comprises 7 m of stratified clay to gravel resting on till or bedrock. Don fossils grade upward from basal warm climate indicators through a cooling sequence. The unconformably overlying deltaic Scarborough Formation, 45 m of sand over clay, contains fossils indicating much cooler climate; water level in the Ontario basin was about 30 m higher than in Don time, suggesting ice blockage of the St. Lawrence valley. Reopening of St. Lawrence drainage (St. Pierre Interstade?) is suggested by deep valleys cut as much as 45 m into the Scarborough and Don Fms; thick channel fill deposits comprise the Pottery Road Formation. Some warming is inferred at this time but is poorly documented by the contained fossils. Initial glaciation at Toronto is represented by the overlying Sunnybrook Till.

These units are beyond the normal range of C^{14} dating, and an absolute chronology depends on application of new dating methods not yet fully developed and proven. Otherwise, qualitative estimates can only be derived from inferred geological relationships and rates of process action such as isostatic uplift, valley cutting, sedimentation, ice advance and retreat, etc.

Evidence at hand suggests that the change from full interglacial to full glacial was gradual and oscillatory, and probably spanned more than 10,000 years.

A.A.

439. **KARROW, P.F., and T.W. ANDERSON. 1975. Palynological study of lake sediment profiles from southwestern New Brunswick: discussion. Canadian Journal of Earth Sciences 12(10):1808-1812.**

The authors refer to the results obtained by Mott (1975); their discussion is focussed on some problems of radiocarbon dating of calcareous materials. The effects of various factors, such as landscape evolution, compaction, and sedimentation rate, on ages in sediment profiles are illustrated. The authors "would emphasize the need to identify as specifically as possible, materials being radiocarbon dated, to regard with suspicion bog bottom dates as minimum dates for deglaciation, and to bear in mind the possibility of old carbonate errors in the dating of many materials, particularly marl, shells, gyttja, and aqueous plant material."

A.B.S.

440. **KARROW, P.F., T.W. ANDERSON, A.H. CLARKE, L.D. DELORME, and M.R. SREENIVASA. 1975. Stratigraphy, paleontology, and age of Lake Algonquin sediments in southwestern Ontario, Canada. Quaternary Research 5(1):49-87.**

Molluscs, ostracodes, diatoms, pollen, plant macrofossils, peat, and wood have been found in glacial Lake Algonquin sediments, and estuarine-alluvial sediments of the same age, in southern Ontario. Molluscs and ostracodes are particularly abundant and widespread. Pollen analysis of Lake Algonquin sediments, bogs on the Algonquin terrace, and upland bogs above the Algonquin terrace, indicate that Lake Algonquin was still in existence at the time of the Spruce-Pine pollen transition, previously dated at an average of 10,600 yr BP at a number of sites in Michigan, Ohio, and southern Ontario. Wood in estuarine-alluvial sediments graded to the Algonquin level is of similar radiocarbon age. Evidence from several sites in the eastern Great Lakes area suggests the presence of a preceding low-water stage (Kirkfield outlet stage); drowned and alluviated valleys and fining-upward sediment sequences have been identified in this study as further supporting evidence. Lake Algonquin drained from the southern sites by isostatic tilting and eventual opening of the "North Bay outlet" some time shortly after 10,400 yr BP.

Our radiocarbon dates suggest the low-water stage has an age of about 11,000 yr BP, and that Lake Algonquin drained 10,000-15,000 y.a. Dates previously published for the Lake Michigan basin are generally too young in comparison with ours, and dates on the Champlain Sea are generally too old. More critical evaluation of all dating results is desirable.

From fossil remains we suggest a rapidly expanding fauna in the waters of Lake Algonquin. The spruce pollen period was a time of rapid faunal and floral migration, when the ice front was retreating from Kirkfield to North Bay, Ontario. Diversity of some species and fossil numbers increased substantially at the transition from spruce to pine just before Lake Algonquin drained.

A.A.

441. **KARROW, P.F., J.R. CLARK, and J. TERASMAE. 1961. The age of Lake Iroquois and Lake Ontario. Journal of Geology 69(6):659-667.**

Recent geological and engineering investigations at Hamilton, Ontario, have resulted in the discovery of buried plant-bearing beds in deposits of Lake Iroquois and Lake Ontario. Fossils in these beds indicate cold, shallow-water conditions of sedimentation for the earlier-deposited beds and warmer conditions for later-deposited layers. Radiocarbon dating of buried wood suggests that Lake Iroquois was formed during the retreat of Port Huron ice.

The Valders drift boundary is inferred to be north of Lake Ontario. Lake Ontario probably began over 10,000 years ago.

A.A.

442. KARROW, P.F., A.H. CLARKE, and H.B. HERRINGTON. 1972. Pleistocene molluscs from Lake Iroquois deposits in Ontario. Canadian Journal of Earth Sciences 9(5):589-595.

Nearly 30 taxa of Pleistocene freshwater snails and sphaeriids have been found in recent years at eight localities in glacial Lake Iroquois deposits. Older reports of molluscs from Lake Iroquois deposits by Ami (1900) and Coleman (1899, 1933) probably represent confusion with shells from Lake Algonquin and Wisconsinan interstadial deposits at Toronto.

Molluscs are most abundant in shallow-water sediments deposited in former lagoons and near former river mouths in Lake Iroquois. A northeastward limit of occurrences near Oshawa, Ontario may reflect the influence of the retreating ice-margin in eastern Ontario 12 000 years ago. Shells have been found occasionally in deposits of lower level, post-Iroquois (but pre-Champlain Sea) lake stages in eastern Ontario. The Lake Iroquois fauna suggests the presence of vegetation both on land and in the water with water conditions at individual sites varying from oligotrophic to eutrophic.

A.A.

443. KARROW, P.F., R.J. HEBDA, and E.W. PRESANT. 1978. Interstadial (middle Wisconsinan?) paleosol and fossils from Guelph, Ontario. Geological Society of America, Abstracts with Programs 10(7):432.

The Victoria Street railway underpass excavation revealed an upper sandy till (Port Stanley) over a hard coarse middle till (Catfish Creek) over a stratified sand and silt and weathered diamicton (colluvium?). An underlying lens of organic sediment rested in a depression on a paleosol developed on sand and gravel. Below the gravel, a lower till rests on Silurian Guelph Dolomite. Three continuously-cored holes were drilled to supplement the information from the temporary cut exposures.

The organic lens and overlying stratified sediments contain pollen dominated by pine and spruce, with some deciduous types. Aquatic plant macrofossils and insect remains are also present. Terrestrial and aquatic molluscs and ostracods record the local pond environment of the organic lens. A radiocarbon date of 35,000 years suggests a Port Talbot or older age.

The paleosol in the gravel is deep enough to suggest a long time or warm climate. Development of a Bt horizon is indicated by clay, Fe, Al, and Mn accumulation. Interstadial paleosols are rare in Southern Ontario and have had little study. All of the few sites known apparently are of Port Talbot age.

A.A.

444. KARROW, P.F., R.J. HEBDA, E.W. PRESANT, and G.J. ROSS. 1982. Late Quaternary inter-till paleosol and biota at Guelph, Ontario. Canadian Journal of Earth Sciences 19(9):1857-1872.

A paleosol and overlying fossiliferous sediments were exposed between an underlying glacial till of Illinoian or early Wisconsin age, and overlying tills (probably including two of late Wisconsin age - 25,000 to 14,000 years B.P.) along Victoria Road in Guelph, Ontario. The Guelph paleosol is probably best classified as a Gleyed Brunisol or a weakly developed Gleyed Luvisol. Since it is like many of the present soils of southern Ontario, presumably the Guelph paleosol would have taken 10,000 or more years to develop under climatic conditions similar to those in the region now. Organic pond sediments overlying this soil contained remains of plant macrofossils, pollen, molluscs, arthropods and insects, indicating a cooler and drier climate than present. Fine organic material from these sediments yielded radiocarbon dates of >45,000 years B.P. (WAT-310, WAT-367), and the authors suggest the intertill deposits may be of Sangamon interglacial or early middle Wisconsin age.

C.R.H.

445. **KARROW, P.F., and J. TERASMAE. 1970. Pollen-bearing sediments of the St. Davids buried valley fill at the Whirlpool, Niagara River gorge, Ontario. Canadian Journal of Earth Sciences 7(2):539-542.**

Continued studies of the buried St. Davids gorge, an ancient valley of the Niagara River, have indicated that the upper part of the gorge was filled in mid-Wisconsinan time and later. Lacustrine sediments dated at 23 000 years B.P. were deposited in the gorge when the late Wisconsinan ice caused the water level to rise in the Lake Ontario basin by blocking the eastern outlet, prior to overriding the Niagara area. Palynological studies support the correlation of the dated lacustrine deposits in the gorge with the Plum Point Interstade of southern Ontario.

A.A.

446. **KAY, P.A. 1978. Dendroecology in Canada's forest-tundra transition zone. Arctic and Alpine Research 10(1):133-138.**

Black spruce in forest outliers has a slower growth rate, more high frequency variation, and less persistence than at the forest limit. Climate variation accounts for more variance in ring widths at the forest limit than within outliers, which occupy protective sites that mitigate stress. Growth behaviour at the forest limit can be interpreted in terms of Arctic Front positions. A two-century long chronology of tree growth is presented. [This study is from the eastern Northwest Territories.]

The statistically significant results indicate that mild summers and dry conditions (indicating relatively cloud-free conditions) favor wide ring widths, whereas cool and wet (cloudy) summers favor narrow ring widths. Precise details of the climate/growth relationship will aid in accurate paleoclimate reconstructions.

A.A.+

447. **KAY, P.A. 1979. Multi-variate statistical estimates of Holocene vegetation and climate change, forest-tundra transition zone, NWT, Canada. Quaternary Research 11(1):125-140.**

Newly derived fossil pollen data were obtained from four sites along a transect from the boreal forest limit into tundra in the eastern Northwest Territories. Multivariate statistical analyses were employed to interpret the pollen assemblages. Transfer functions were constructed between the pollen data and climatic data, and paleoclimatic estimates were derived. The objective nature of the reconstuctions provides an independent verification of the general outlines of the chronology of tree-line movements during the mid- and late-Holocene as established in previous paleosol and pollen studies. Boreal forest extended to approximately 62°N, associated with mean July temperatures 1 to 3°C above modern means, from at least 5500 to 3700 B.P. Although a major episode of southward displacement of tree line at about 3700 yr B.P. is recorded, later events are not clearly represented. Considerations of the statistics, the time scales, and the nature of the pollen rain suggest only conservative interpretations of the results are possible. It is suggested that the pollen sites may have been sensitive recorders of regional vegetation change only when they were near the ecotone, corresponding to a climatic threshold.

A.A.

448. KEARNEY, M.S., and B.H. LUCKMAN. 1981. Evidence for late Wisconsin-early Holocene climatic/vegetational change in Jasper National Park, Alberta. In: Quaternary Paleoclimate. Edited by: W.C. Mahaney. Geo Abstracts, Norwich. pp. 85-105.

Basal C^{14} dates of 9660 and 9600 yr. BP from two sites close to the Continental Divide indicate late-Wisconsin glaciers had receded to positions at or close to their present limits prior to 10,000 yr. BP. The deposits of two subsequent glacial advances have been recognized by Luckman and Osborn (1979). The older advance (Crowfoot) is represented by moraines and rock glacier deposits which predate 6600 yr. BP. The younger advance (Cavell) was usually the most extensive Holocene glacial event and shows very limited rock glacier development. Intermediate-age advances may occur on some rock glaciers, but no absolute dating control is available for these features.

Preliminary pollen diagrams are presented for the early Holocene period (c. 9700-5000 yr. BP) for 3 sites in different ecological environments: Excelsior Basin (2150 m, above treeline), Tonquin Creek (1935 m, subalpine) and Maligne Lake (1675 m, montane forest). Three major vegetation/climatic zones are recognized but the two oldest are present only in the Tonquin diagram and have no contemporary analogues in pollen rain data from the area. The earliest zones (9700-9200 yr. BP) dominated by the pollen of *Pinus contorta* and Polypodiaceae may be largely seral in nature or indicate slightly warmer conditions than present. The succeeding *Pinus albicaulis - Abies lasiocarpa - Picea engelmanii* zone (9200-8500 yr. BP) suggests slightly cooler conditions. The Hypsithermal Interval (8500-5500 yr. BP) is present at all three sites and has two warmer phases separated by a cooler period between 8000-7500 yr. BP. Palynological and macrofossil evidence indicates that during the warmer periods valley floor sites dried out and treeline advanced at upper elevations. Dated tree remains from sites above present treelines confirm the occurrence of higher treelines than at present c. 980, 5920 and 8060 yr. BP. The available pollen data suggest that the Crowfoot Advance occurred between 9200-8500 yr. BP or predates 9700 yr. BP.

A.A.

449. KELLER, G. 1978. Late Neogene climatic oscillations across the mid-latitudes of the North Pacific. Geological Society of America, Abstracts with Programs 10(7):433.

Frequency distributions of temperature sensitive planktonic foraminiferal species identify five major paleoclimatic cool events extending across the mid-latitudes of the North Pacific. A major cooling occurred during the latest Miocene to early Pliocene. This period is followed by a short cooling at about 3.2 - 3.4 m.y. Warmer temperatures resumed during the late Pliocene followed by a cool period commencing at about 2.4 m.y. Warm but oscillating temperatures prevailed during early Pleistocene followed by a cooling at about 1.2 m.y. A further cooling is indicated during the late Pleistocene beginning at about 0.7 m.y. ago. Paleoclimatic interpretations based on frequency distributions of planktonic foraminifera are supported by oxygen isotope analysis.

pA.A.

450. KELLOGG, W.W. 1981. Climate change and society: environmental effects and societal consequences of climate change induced by increasing carbon dioxide. In: Climate Change Seminar Proceedings. Regina, March 17-19. Canadian Climate Centre, Downsview. pp. 129-153.

While we may never be able to predict future climatic change and how societies will respond to it, we can clarify the relative merits of alternative long-term policies of strategies. We believe that the most useful strategies are those that can mitigate the adverse impacts of the changes and make specific activities--such as agriculture and human settlements--less vulnerable to climatic impacts from whatever cause.

Having made an initial (and by no means exhaustive) examination of the various strategies, we can see that each one will also help cope with short-term weather and climate variability--

devastating events such as droughts, floods, heat waves, and cold spells that cause hardship every year. Some strategies will also help alleviate chronic environmental problems such as the loss of arable soil and tropical forests; international and national measures to preserve these precious natural assets are long overdue. Perhaps the stimulus of an impending climate change will help to spur such actions.

Climatic impact studies will help to estimate the effects of climatic changes, which should enable us to better plan agriculture production, land use, and human settlements, and to develop water resources and marketing strategies. However, new and improved methodologies of climate impact assessment are needed as well as more scientists interested in working on impact studies.

Apart from the research needed to improve our ability to carry out impact studies, it is imperative that we implement international programs to cope with carbon dioxide-induced changes. Some international mechanisms already exist that might help us deal with this unprecedented set of global problems. All of them should be explored and their use encouraged. Most importantly, nations should be made aware of the problem of climatic change and of the strategies that could mitigate its effects.

For some countries the change may be favourable, while for others it may be adverse. But we must emphasize that the prospect of a global climatic change is just one of a number of global environmental and societal problems. In the first half of the next century the world could well have twice as many people, consume three times as much food, and burn four times as much energy. Thus, impacts of climatic change must be superimposed on this backdrop. Our future problems will be serious even without a shifting climate.

pA.C.

451. **KELLY, P.M., P.D. JONES, C.B. SEAR, and B. CHERRY. 1981. Variations in arctic surface air temperature 1881-1977. First Conference on Climate Variations of the American Meteorological Society, January 19-23, San Diego. Abstracts, p. 22.**

Annual and seasonal changes in Arctic air temperature over the period 1881-1977 are described. The analysis is based on a new data set containing homogenized and gridded instrumental station data for regions north of 65°N. Trends in the average temperature of the Arctic are compared with those of the Northern Hemisphere, and it is shown that the rapidity, as well as the magnitude, of the longer-term fluctuations (on time scales greater than 20 years) are greater in higher latitudes. Characteristic spatial patterns of variation in the Arctic temperature field are determined by eigenvector analysis. Longer term trends are strongest over northwest Greenland in winter and northwest Siberia in other seasons. Interannual fluctuations are strongest over the ice-edge in the Barents Sea and over the shelf seas off Siberia and Alaska. These interannual fluctuations show evidence of characteristic time scales of variation, which may be related to processes of sea-ice formation, advection, and decay.

A.A.

452. **KENDALL, G.R., and M.K. THOMAS. 1956. Variability and trends of precipitation in the Prairie Provinces. Canadian Society of Agronomy, Proceedings of the Second Annual Meeting, Toronto. pp. C.17-30.**

Precipitation in the agricultural portion of the Canadian Prairies ranges from 12 to 22 inches on the average, and has a well marked maximum in the summer season. The range of the coefficient of variation of annual precipitation is 20 to 28 per cent, the higher values occurring in the drier sections of the area. Using data for the period 1891 to 1955, it is shown that heavy precipitation during the first decade of this century was followed by a long period of generally subnormal precipitation. During the early 1950s however, precipitation has again increased to a relatively high level.

A.S.

453. KERR, D.P. 1951. Methods in paleoclimatology with reference to Canada. Royal Meteorological Society, Canadian Branch 2(7):1-6.

The author introduces Paleoclimatology and reviews the literature with particular reference to Canada.

Thomas

454. KETCHEN, K.S. 1956. Climatic trends and fluctuations in yield of marine fisheries of the northeast Pacific. Journal of the Fisheries Research Board of Canada 13(3):357-374.

Mean annual air temperature at San Francisco, California, New Westminster and Masset, British Columbia, all had a rising trend from 1920 to 1940, then declined to 1950. Amplitude was greatest at Masset, least at San Francisco. The 20-year rise is similar to the story in the North Atlantic Ocean, but the recent decline has no parallel there. Prior to 1920 there were considerable differences among the above three stations. Mean annual ocean temperature at Nanaimo, B.C., is similar to air temperature at New Westminster since 1915. "Winter" ocean temperatures (February-April) show similar but not identical trends, and are thought to best represent conditions at the time eggs and larvae of most commercial bottom fishes are in the water.

Suggestive short-term correlations have been observed as follows: 1. a positive correlation between winter temperature and abundance of brill 6 years later; 2. a negative correlation between winter temperature and rock sole abundance 5 years later; 3. a negative correlation between winter temperature and strength of year-classes in lemon sole. Over a long period, there is much resemblance between the temperature history since 1910 and the abundance of halibut broods, as indicated by catch per unit effort 10 years later (southern grounds) or 12 years later (western grounds). The relationship is positive, and for western grounds is similar even in details. Over a somewhat shorter period, blackcod abundance has varied inversely with winter temperature. Marked changes in abundance and distribution of true (grey) cod since about 1900 cannot be related to temperature series available.

A.A.

455. KHAN, E. 1970. Biostratigraphy and palaeontology of a Sangamon deposit at Fort Qu'Appelle, Saskatchewan. National Museum of Natural Sciences Publications in Palaeontology (Ottawa) No. 5:1-82.

A gravel pit ½ mile southwest of Fort Qu'Appelle, Saskatchewan, was studied. Pleistocene vertebrate fossils were found in the Echo Lake gravels, which lie between 170 ft of overlying and 150 ft of underlying till. The upper sand layer, whichwas 20 ft thick, yielded no vertebrate remains, but did contain four aquatic and four terrestrial species of invertebrates. Vertebrate fossils were collected from four gravel beds, with channel B of the third gravel bed being the most fossiliferous.

Remains of *Canis* sp., *Taxidea* sp., *Mammuthus* cf. *columbi*, *Equus scotti*, *Camelops* cf. *hesternus*, *Cervalces roosevelti*, *Bison latifrons*, and *Symbos cavifrons* were identified.

These species can be regarded as temperate climate animals, except for *Symbos*, which may have been adapted to cold conditions. The presence of their remains in the gravel beds indicates that the gravels are interglacial stream deposits rather than outwash deposits. A grassland environment is envisioned for the fauna because of the predominance of remains of grazing animals. The biostratigraphic evidence strongly suggests a Sangamon interglacial age for the faunal assemblage.

The upper sand layer, a periglacial deposit, evidently was laid down when the river's flow to the east was obstructed. It represents either a cold phase within the Sangamon or the beginning of the Wisconsin glaciation.

A.S.

456. KING, L.H. 1976. Relict iceberg furrows on the Laurentian Channel and western Grand Banks. Canadian Journal of Earth Sciences 13(8):1082-1092.

A side-scan sonar survey along the western bank of the Laurentian Channel and on the western Grand Banks revealed the occurrence of iceberg furrows that are probably of Late Pleistocene age. The occurrence of furrows in the Gulf of St. Lawrence is significant in that it helps to date iceberg furrows along the northeast Newfoundland-Labrador margin of the northwest Atlantic, provides data on the history of deglaciation of the offshore area of the Atlantic Provinces, provides a means of evaluating sea level curves, and provides additional evidence for the broad regional extent of the Late Pleistocene shoreline at 115 to 120 m.

A.A.

457. KING, R.H., and G.R. BREWSTER. 1974. Pedogenesis in a subalpine environment. In: Quaternary Environments: Proceedings of a Symposium. Edited by: W.C. Mahaney. First York University Symposium on Quaternary Research. Geographical Monographs No. 5:277 (Abstract).

Soil genesis in the Bow Pass area of Banff National Park, Alberta, is examined for changes in soil development that have occurred since deglaciation. Following deglaciation within the subalpine zone at approximately 10,000 years BP, initial pedogenesis in a calcareous till was interrupted by the deposition of a complex aeolian material containing large amounts of volcanic ash. Previous research in the area has established the presence of three separate ash layers; Mazama ash, dated at 6,500 years BP, St. Helen's Y ash (3,500 years BP), and Bridge River ash (2,500 years BP). However, site instability within the study area, due to a variety of geomorphic processes, has resulted in an intermixing of the various ash layers. Nevertheless, it is possible to differentiate the loessic mantle from the underlying till using mineralogical and particle-size parameters. Pedogenesis subsequent to the deposition of the loess has involved both parent materials. Although this makes the identification of specific pedogenic processes extremely difficult, Brunisols, Podzols, and Luvisols have been identified within the subalpine zone.

pA.A.

458. KINSMAN, W.A. 1981. Impact of climate change and variability on water and other related resources. In: Climate Change Seminar Proceedings. Regina, March 17-19. Canadian Climate Centre, Downsview. pp. 43-50.

"The increasing variability of weather conditions and possible warming effects will significantly alter the hydrologic characteristics which will affect the availability of water to meet present and future demands. The problems of water management relating to hydrologic design and forecasts will become more serious and widespread. The need for a better understanding of the climate and the use of climatic data for hydrologic forecasts will assume added importance. Only with adequate climatic data can we reliably forecast the impact of climate change and variability on our resources and environment."

The author outlines Newfoundland's current climatological network and the areas which require attention. Recommendations designed to facilitate gathering of appropriate data are proposed.

A.B.S.

459. KLASSEN, R.W. 1972. Wisconsin events and the Assiniboine and Qu'Appelle valleys of Manitoba and Saskatchewan. Canadian Journal of Earth Sciences 9(5):544-560.

The Assiniboine and Qu'Appelle valleys formed as spillways and meltwater channels, mostly within partly re-excavated ancestral valleys of probable Early Wisconsin age. It is unlikely this region was glaciated in Mid-Wisconsin time and the Late Wisconsin glaciation was relatively weak resulting in only partial infilling of Early Wisconsin valleys with Alluvium, drift, and ice. The alluvial fill below the valley bottoms commonly includes a thick (100 to 200 ft (30.48 to 60.96 m)) lower unit mostly of Mid-Wisconsin and Late Wisconsin age, and a thinner (60 to 100 ft (18.28 to 30.48 m)) upper unit of Late Wisconsin and Recent Age.

The modern valley system formed between 15 000 and 12 000 years ago. The Qu'Appelle Valley was cut to its maximum late glacial depth more than 14 000 years ago and the Assiniboine Valley about 12 000 years ago. Subsequent infilling of most parts of the valleys with alluvium and colluvium has continued at a gradually diminishing rate to the present.

A.A.

460. KLASSEN, R.W. 1978. A unique stratigraphic record of late Tertiary-Quaternary events in southeastern Yukon. Canadian Journal of Earth Sciences 15(11):1884-1886.

A succession of fluvial sediments with minor coal, basaltic lava, five tills, and fossiliferous intertill sediments exposed along the Liard River where it crosses the Liard Plain provides a remarkably continuous record of geologic-climatic events in this region. The coal bearing sediments and lava were previously described and interpreted as Tertiary-Quaternary in age. The Quaternary sediments record four major intervals of glaciation and three nonglacial intervals not previously recognized in this region.

A.A.

461. KLASSEN, R.W., L.D. DELORME, and R.J. MOTT. 1967. Geology and paleontology of Pleistocene deposits in southwestern Manitoba. Canadian Journal of Earth Sciences 4(3):433-447.

Sediments containing fossils and organic material occur within Pleistocene deposits underlying multiple tills in the Duck Mountain and Riding Mountain Uplands of southwestern Manitoba. Pollen, ostracods, and mollusks within the sediments on Duck Mountain indicate a cool-warm-cool climatic sequence, which began more than 37 760 years B.P. Bones of a ground squirrel (*Citellus*) and vole (*Microtus*) were recovered from an intertill silt on Riding Mountain. Grass associated with the bones was dated as more than 31 300 radiocarbon years B.P.

The sediments may be correlative with some of the beds of the recently redefined Port Talbot interstade in the Lake Erie region, though it is inferred they are older and correlative either with an early Wisconsin interstade or with the Sangamon interglacial in the mid-western United States.

A.A.

462. KNOX, J. 1981. Blocking in the Northern Hemisphere. First Conference on Climate Variations of the American Meteorological Society, January 19-23, San Diego. Abstracts, p. 8.

The incidence of blocking in the Northern Hemisphere from 1946-78 has been examined by the use of "blocking signatures." These are 500 mb positive height anomalies related to blocking episodes, which qualify according to empirically derived thresholds of latitude and anomaly intensity. Areal and longitudinal frequency distributions confirm the findings of previous investigations for the oceans. However, there is strong evidence that a much higher incidence of blocking occurs over eastern Siberia, the Arctic Ocean, and northeastern Canada than the literature would suggest. Typical synoptic evolutions associated with blocking over these three regions will be illustrated. Findings concerning wavenumber signatures associated with Atlantic and Pacific blocking will also be presented with particular emphasis on the winter of 1978-79. Variation of blocking frequency since 1946 will be examined for secular change.

A.A.

463. KOERNER, R.M. 1977. Devon Island ice cap: core stratigraphy and paleoclimate. Science 196(4285):15-18.

Valuable paleoclimatic information can be gained by studying the distribution of melt layers in deep ice cores. A profile representing the percentage of ice in melt layers in a core drilled from the Devon Island ice cap plotted against both time and depth shows that the ice cap has experienced a period of very warm summers since 1925, following a period of colder summers between about 1600 and 1925. The earlier period was coldest between 1680 and 1730. There is a high correlation between the melt-layer ice percentage and the mass balance of the ice cap. The relation between them suggests that the ice cap mass balance was zero (accumulation equaled ablation) during the colder period but is negative in the present warmer one. There is no firm evidence of a present cooling trend in the summer conditions on the ice cap. A comparison with the melt-layer ice percentage in cores from the other major Canadian Arctic ice caps shows that the variation of summer conditions found for the Devon Island ice cap is representative for all the large ice caps for about 90 percent of the time. There is also a good correlation between melt-layer percentage and summer sea-ice conditions in the archipelago. This suggests that the search for the northwest passage was influenced by changing climate, with the 19th-century peak of the often tragic exploration coinciding with a period of very cold summers.

A.S.

464. KOERNER, R.M. 1980. Basal ice and paleoclimate. Eos 61(5):50 (Abstract).

A series of ice cores from two Canadian High Arctic ice caps have given insight into the nature of the ice/bedrock interface there, both past and present. Three of these cores (two are 299 m and one 337 m long), located 1-2 km down the flowline on Devon Island and northern Ellesmere Island, show there is a sharp interface between bedrock and basal ice. There are no rock fragments or floor frozen within the ice. The evidence strongly points to the ice caps having been frozen to their beds throughout their 100,000 year history. Another core (137 m long), taken this May, 1979, at the top of the flowline on a northern Ellesmere Island ice cap, contained 2.75 m of ice containing a high clay fraction at its base. The nature of the inclusions suggests substantial bottom melting of the ice cap at some stage during its history. The present interpretation is that this dirty basal ice at the top of the present northern Ellesmere ice cap flowline dates from a pre-Wisconsin ice age when the ice cap was thick enough to melt at its bed. It has survived the Sangamon interglacial, unlike the very old ice at the other downslope sites, because of the greater elevation of the bedrock at the upper site. It means that the Wisconsin ice sheet was substantially thinner on Ellesmere Island than the earlier ice sheet. It also means that the ice caps expanded downslope during what is presently identified as an interglacial period preceding the Wisconsin ice age.

A.A.

465. KOERNER, R.M., and D.A. FISHER. 1979. Liquid natural gas transport through Parry Channel and climatic change. Energy, Mines and Resources Canada Internal Report. 19 pp.

The unique warmth of the first half of this century is emphasized, and a prediction of a 1°C annual, and a 1-2°C summer cooling over the next 50 years is given. The authors stress that planning should be made on the basis that the coldest summer of the last 10 years will be the norm of the next 50 years.

A.A.

466. KOERNER, R.M., and D.A. FISHER. 1979. Discontinuous flow, ice texture, and dirt content in the basal layers of the Devon Island ice cap. Journal of Glaciology 23(89):209-222.

Surface-to-bedrock cores obtained with a CRREL thermal drill were taken in 1972 and 1973 from the top of the Devon Island ice cap. There are very pronounced variations in oxygen isotope, microparticle concentration, and ice texture in the lowermost 5 m of the core. There is a section of isotopically cold, very fine bubbly ice with high micro-particle concentrations between 2.6 and 4.4 m above the bed, considered to represent the Last Ice Age. There is coarse, isotopically warm, clean ice above and below this. For 1.2 m above the bed, the ice is finer again with high micro-particle concentrations but it shows very low bubble concentration and is isotopically the warmest in the core. While the broad variations are common to both cores, in detail there are significant variations despite the fact that the cores were taken only 27 m apart. The variations, when analysed statistically, show that at least 25-30% of the originally continuous profile is missing from each core. Faulting within the near-bedrock ice may be responsible for some of the effect but bubble fabric also gives evidence for irregular nonlaminar flow. Because of the strong relationship between crystal size and micro-particle concentrations in the Devon Island cores, it is suggested that the fine-grained nature of dirty layers in the Antarctic and Greenland ice sheets is due to the effect of the dirt inclusions and of shearing. Steep isotopic gradients in the Devon Island cores are shown to be evidence for possible shearing, which does not effect any change in the crystal texture. Clear ice near the bed is considered a tectonic feature, but the lack of effect on its bed by the ice cap confirms the non-erosional nature of an ice cap frozen to its bed.

In terms of paleoclimatic history, it means that, because of bedrock effects, ice caps of intermediate depth (i.e. < 400 m) can give continuous information only over the last approximate 5000 years. Between 5000 and 10000 BP the time series becomes slightly discontinuous and beyond 10000 BP so discontinuous as to allow only broad climatic inferences to be drawn.

A.A.

467. KOERNER, R.M., and D.A. FISHER. 1981. Studying climatic change from Canadian High Arctic ice cores. In: Climatic Change in Canada 2. Edited by: C.R. Harington. Syllogeus 33:195-218.

The Polar Continental Shelf Project began its drilling program in 1965 with an 112 m thermally drilled surface-to-bedrock core (M65) on Meighen Ice Cap. The program continued with a 212 m core on Devon Island Ice Cap in 1971 (D71), and two surface-to-bedrock cores 299 m in length from the same ice cap in 1972 and 1973 (D72, D73). Presently we are engaged in drilling on the Agassiz Ice Cap on Northern Ellesmere Island where, to date, a 337 m core (Ag77) and a 137 m core (Ag79) have been drilled. Both extend from the surface to bedrock. All these cores come from, or close to, the top of the flow-line on each ice cap.

The main conclusion we can draw from D72 and D73 cores is that, generally, High Arctic climate has been cooling over the past 5,000 years. However, the δ record represents annual temperatures, and a shorter record of summer melting in the same cores suggests that while the summer temperature changes lag behind the annual ones, there may be a more complex and generally poor relationship between the two. Thus, the present negative balance of the Devon Island Ice Cap and the Meighen Ice Cap climatic record can be much better related to the summer melt record, and in particular, summer paleotemperatures as seen in certain Arctic pollen records. As far as summer climate is concerned, our cores show a very warm period 20-70 years BP, and another from about 1000-2000 BP.

We are unable to determine the driving force behind the overall temperature decline at the drill sites, a trend which is in general agreement with other proxy temperature records elsewhere in the Northern Hemisphere. We have good evidence that neither increasing volcanic activity nor changing turbidity are the causes. We predict that the cooling in the High Arctic will continue for about another 50 years. The cooling will be of the order of 0.5-1°C. We think that summers will cool for about 20-50 years longer than the annual temperatures, and by about twice the amount of annual cooling. These predictions do not include any anthropogenic effects which may, for example in the case of CO_2 generation, counteract the cooling effect. Our future concerns are with our Ag77 and Ag79 cores where we have an improved time scale based partly on volcanic layers.

Generally, our cores indicate that the large ice caps on Devon, Ellesmere and Axel Heiberg Islands are about 100,000 years, or more, old. The Meighen Ice Cap and Ward-Hunt Ice Shelf probably began their growth as conditions grew more favourable for glacierization 4,000 years ago. The remaining small ice caps are probably younger still, beginning growth at the end of the warm period 2000-1000 years ago which formed dirt layers on the Ward-Hunt Ice shelf and a relic ablation surface on the Meighen Ice Cap. This is because a large number of the small ice caps are 40 m, or less, thick and probably would not have survived the 1000-2000 BP warm period.

A.C.+

468. **KOERNER, R.M., and W.S.B. PATERSON. 1974. Analysis of a core through the Meighen Ice Cap, Arctic Canada, and its paleoclimatic implications. Quaternary Research 4(3):253-263.**

Analyses of crystal size, bubble content, oxygen isotope ratio, specific electrolytic conductivity, and the distribution of firn and dirt layers in a core, 121.2 m long, from surface to bedrock near the highest point of the Meighen Ice Cap, leads to the following outline of the ice cap's history. The ice cap, which has always been stagnant, originated in the cold period that followed the postglacial Climatic Optimum. After initial growth came a period of negative mass balance in which the area and thickness of the ice cap diminished and the surface slope at the core site steepened. The end of this period, at least 600 y.a., is marked by a discontinuity at 54 m. depth in the core; above this level, the values of most parameters differ significantly from their values below. There followed a period of growth by the end of which, some 80 y.a., the ice cap had attained its maximum thickness; this period included the coldest interval in the ice cap's history. Ablation has predominated since then and up to 13 m of ice have been lost at the core site. This history resembles that of the Ward Hunt Ice Shelf.

A.A.

469. **KOERNER, R.M., W.S.B. PATERSON, and H.R. KROUSE. 1973. $\delta^{18}O$ profile in ice formed between the equilibrium and firn lines. Nature Physical Science 245(148):137-140.**

Accumulation throughout the history of the stagnant Meighen Ice Cap in the northern Canadian Arctic Islands has been almost entirely in the form of superimposed ice with occasional years of firn accumulation - a mode of accumulation quite different to that in most of Antarctica and Greenland. Analyses of cores pose a few problems. The palaeoclimatic value of ^{18}O profiles in areas close to the equilibrium and firn lines of subpolar ice caps is limited by: 1) a relatively complex relationship between the original δ value of the snow cover and the final δ value of the annual superimposed ice layer, the relationship depending mainly on whether summer precipitation forms part of the annual ice layer; 2) the effect of isotopic enrichment of the solid phase during the process of meltwater percolation through recrystallising snow; 3) ablation of annual layers in warm summers. The isotope data has nevertheless proved valuable in confirming that the Meighen Ice Cap is post-Wisconsin in age (probably between 5,000 and 10,000 years old).

L.G.

470. KOERNER, R., and R.D. RUSSELL. 1979. $\delta^{18}O$ variations in snow on the Devon Island ice cap, Northwest Territories, Canada. Canadian Journal of Earth Sciences 16(7):1419-1427.

A study of $\delta^{18}O$ variations of snow samples taken on traverses across the Devon Island ice cap in June 1971, 1972, and 1973 has shown a difference between the accumulation conditions on the southeast and northwest sides of the ice cap. On the southeast side there is an increasing depletion of $\delta^{18}O$ in the snow with increasing elevation. This pattern is attributed to the effect of orographic uplift of air masses moving over the ice cap from the southeast, which promotes condensation and precipitation due to adiabatic cooling. On the northwest side of the ice cap there is no evidence of any further depletion of ^{18}O in snow, neither with increasing distance from the possible moisture source in Baffin Bay to the southeast nor with increasing elevation if the air mass comes from the northwest. In this case condensation is due to isobaric cooling so that precipitation is generally from level cloud bases. The changes inferred for the isotopic composition of the water vapour as it rises up the southeast slope are found to be consistent with its depletion through precipitation under near-equilibrium conditions. It is calculated that approximately 30% of the moisture at sea level on the southeast side of the ice cap and 8% at the top of the ice cap are of local origin. Lower temporal and aerial variability of the δ values on the southeast side of the ice cap is attributed to dominance of the Baffin Bay low on that side effecting consistency of storm conditions there.

The δ values of ice in the ablation zone on the Sverdrup Glacier show the combined effect of ice movement from the accumulation to the ablation zone and climatic change during the period of movement from cold to warm and back to cold conditions again.

A.A.

471. KORPIJAAKKO, M.-L., and N.W. RADFORTH. 1972. On postglacial development of muskeg in the province of New Brunswick. In: Proceedings of the 4th International Peat Congress I-IV, Helsinki. pp. 341-360.

Radiocarbon dates for basal peat in studied muskegs range from 11,000 to 7200 years B.P. The oldest age which is for St. Quentin Bog could account for an earlier ice retreat from this upland and for an immediate initiation of paludification following the deglaciation.

Coastal muskeg areas are results of primary paludification that has taken place after crustal uplift had exposed flat coastal areas. The influence of humid marine climate, which is favourable for paludification, shows not only as a uniform deposit of relatively pure *Sphagnum* peat but also in the early initiation of the growth of Sphagna in large quantities (about 7500 years B.P.) The accumulation of peat (predominantly *Sphagnum*) has been especially vigorous during the last 5000 years. This has resulted in the raised bogs typical especially of the coastal areas.

Further inland (e.g. Bull Pasture Bog and St. Quentin Bog) the filling in of small water bodies by vegetation has been a significant factor in the initiation of paludification which, after that, has proceeded as a primary forestland paludification encroaching on the surrounding mineral terrain.

Regarding the climatic differences as based on pollen diagrams, large scale fluctuations are clearly distinguishable: ice retreat (Zone VII), initial warm period (Zone VI), moist, coolng trend (Zone V), increasing warmth (Zone IV), dry, maximum warmth (Zone IIIb, IIIa), colder and moist (Zones II,I). For description of climatic changes within the province of New Brunswick, the existing material is at present not comprehensive enough, but the authors believe that such a description is possible as well as correlation of postglacial climatic changes on both sides of the Atlantic with further investigations.

pA.C.

472. **KRAUS, E.B. 1960. Synoptic and dynamic aspects of climatic change. Quarterly Journal of the Royal Meteorological Society 86(367):1-15.**

The changing pattern of world climate during the last hundred years is compared with the inferred pattern of the Pleistocene. Relatively cool climates at high latitudes appear to have been associated much of the time with reduced tropical sea-surface temperatures, a lower snow-line on tropical mountains, reduced aridity on the desert fringes and increased storm activity along continental east coasts in middle latitudes. Relatively warm climates at high latitudes tend to be associated with the opposite complex of conditions.

Considerations of the water balance suggest that a small temperature decrease would be necessary and sufficient for the re-establishment of glacial conditions in many regions. Increased snowfall would help but is not essential. Synoptic considerations indicate that glaciation was associated necessarily with strong upper westerlies at relatively low latitudes over the continents and probably with vigorous anticyclones over the subtropical oceans.

An increased infra-red cooling rate in the upper air, particularly over the tropics, could produce all the necessary conditions for the establishment of a glacial/pluvial phase. Possible causes for changes in the infra-red cooling rate are discussed.

[Includes reference to climate change in Canada.]

A.S.+

473. **KUKLA, G. 1981. Climatic role of snow covers. In: Sea Level, Ice, and Climatic Change. Edited by: I. Allison. International Association of Hydrological Sciences Publication 131:79-107.**

Snow cover is the critical variable of the climate system because of its high reflectivity, high emissivity, low water vapour pressure, and low conductivity. Formation and dissipation of snow covers closely depends on the amount, as well as the spectral and the singular distribution of incoming shortwave radiation. The deposition of snow induces a step in the response of surface temperature to insolation forcing. Weak energetic impulses are multiplied by potent feedbacks which operate in the marginal belt of snow and ice, here called the transition zone. Combined impact of the industrial and volcanic aerosols and of the CO_2 on the deposition and melt of the snow in the high and middle northern latitudes is an urgent problem of immediate concern. This is because: (a) the concentration of industrial aerosols and of CO_2 reach a seasonal peak in spring when the sensitivity of snow to energy forcing is high; (b) the future concentrations of aerosols and of CO_2 in high latitudes will be affected by the worldwide energy policies; and (c) contrary to the expectations of climate models, the CO_2 increase in the last 30 years is accompanied by a marked oscillatory cooling of the northern high and middle latitudes.

A.A.

474. **LABELLE, C., et P.J.H. Richard. 1981. Végétation tardiglaciaire et postglaciaire au sud-est du parc des Laurentides, Québec. Géographie physique et Quaternaire 35(3):345-359.**

Pollen analysis of the sediments of three lakes located south-east of the Laurentides Provincial Park served to reconstruct different stages in the post-Wisconsinan vegetational history. Those stages proved to be widespread within the studied area. The first stage (subzone 1a) corresponds to a very open landscape, but the scarce vegetation cover already consisted of many herb and shrub taxa. After a transitional stage (subzone 1b), a very rich tundra-like vegetation occurred (subzone 1c), followed by a shrub-dominated vegetation in which *Betula glandulosa* played an important role (subzone 1d). *Populus* cf. *tremuloides* initiated the afforestation stage (subzone 2a), followed by *Picea mariana*. The afforestation was completed by the immigration of many tree species

(*Betula papyrifera, Pinus* cf. *divaricata, Abies balsamea, Picea glauca* and *Larix laricina*) during the next stage (subzone 2b). The pollen of *Alnus* cf. *crispa* shows maximum abundance within subzone 2b. The dating of these stages is hampered by the lack of chronological control of the largely inorganic sediments to which they belong. However, at least one thousand years passed between ice retreat and the immigration of *Populus* cf. *tremuloides*. The forest vegetation history (zone 3) that followed afforestation has been quite monotonous. Only minor changes of the abundance of species like *Pinus strobus, Picea mariana* and *Pinus* cf. *divaricata* are revealed by the pollen diagrams. Most of the tree species were present very early in the Holocene.

A.A.

475. LAGAREC, D. 1979. Problèmes de paleoclimatologie post-glaciaire du Québec meridional. Geoscope 10(1):7-12.

This article deals with problems related to periglacial in meridional Québec. The subject is broached through three pertinent questions: (1) has meridional Québec known a post-glacial permafrost? (2) when was this permafrost formed? (3) what is the paleoclimatic meaning of these indicators?

A.A.

476. LAMB, H.F. 1980. Late Quaternary vegetational history of southeastern Labrador. Arctic and Alpine Research 12(2):117-135.

Pollen percentage and influx diagrams for three lake-sediment cores from southeastern Labrador are subdivided into three regional pollen assemblage zones: (I) *Betula-Salix*-Cyperaceae zone, 10,500 to 9000 ^{14}C yr BP; (II) *Alnus-Abies-Picea* zone, 9000 to 5000 BP; (III) *Picea* zone, 5000 BP to present. Pollen influx was low in zone I, rose in zone II, and then abruptly increased in the upper part of zone II when tree pollen was first deposited in significant amounts. Influx reached a maximum about 4000 yr ago and declined substantially after 2500 BP.

An early phase of tundra was succeeded 9000 yr ago by *Betula-Alnus* shrub-tundra as the climate warmed. Trees then colonized the shrub-tundra at 6000 BP arriving late relative to sites farther south and west. The initial forest community is interpreted as a park-tundra of *Picea glauca* with abundant *Abies balsamea* and probably with some *Betula papyrifera*. After a period of about 700 yr, *Abies* declined in favor of *Picea mariana* as soil conditions began to deteriorate. The formation of peat was probably accelerated at this time.

The pollen record from a site on the south coast shows that the coastal region was never forested. The pollen influx record shows distinct similarities to that of the inland sites, suggesting that climate was most temperate about 4000 yr ago and that a deterioration took place about 2500 BP.

A.M.

477. LAMB, H.H. 1964. The role of atmosphere and oceans in relation to climatic changes and the growth of ice-sheets on land. In: Problems in Palaeoclimatology. Edited by: A.E.M. Nairn. London. pp. 332-348.

Lamb ... surveys briefly what is known of the changes in extent of ice on land and sea during the last few centuries. In spite of notably great temperature changes between A.D. 1200, 1550-1850 and 1900-1950, it seems clear that there was no significant tendency to start rebuilding the great Pleistocene continental ice-sheets in the northern hemisphere. The findings of recent work on changes in the atmospheric and oceanic circulations during the last 1000 years suggest that the recent cold epoch set in too sharply and in ways that probably rapidly reduced the precipitation in high northern latitudes. Probable causes of this period of cold climate were considered by Lamb and in light of these studies he attempted an appraisal of the current ideas concerning the origins of the Pleistocene glaciation and factors governing the growth and decay of glaciers at the present time.

Editor

478. LAMB, H.H. 1966. The Changing Climate; Selected Papers. Methuen, London. 236 pp.

A collection of papers by one of the leading scholars in the field of climatic changes and trends. Several chapters contain arctic material, and chapter 5, p. 140-56, reviews the role of atomsphere and oceans in relation to high-latitude climatic change and the growth of ice sheets on land. Displacements in the mean direction of depression tracks are viewed as highly significant. The problem of identifying eustatic change in sea level is briefly considered, and snow accumulation on Greenland is discussed with map and graphs. A number of theories of ice age development are briefly reviewed. The author considers an Arctic Ocean ice-free on the Atlantic side of the Lomonosov Ridge but frozen on the Alaskan side to offer a possible compromise between the views of Ewing and Donn, and Karlstrom.

A.B.

479. LAMB, H.H. 1969. Climatic fluctuations. In: World Survey of Climatology, Volume 2, General Climatology 2. Edited by: H. Flohn. Elsevier, Amsterdam. pp. 173-249.

Long-term changes of climate are the result of changes in the general circulation of the atmosphere. The chapter has six sections: climatic history, the record of instrumental observations, circulation studies, the extension of the circulation analysis to the years before 1750, the nature of the Little Ice Age (1430-1850) and a summary of causes and course of climatic variations. This last section includes study of variation in solar output, variation of the astronomical relationship between the earth and the sun, the effect of CO_2 and water vapour on the transmission of energy through the atmosphere, variations in albedo, in the amount of heat stored in the oceans and in the extent of polar ice. While data are quoted from all over the world, the largest historical records are from NW Europe, and most of the maps refer to the northern hemisphere.

G.A.

480. LAMB, H.H. 1972. Climate: Present, Past and Future. Volume 1. Fundamentals and Climate Now. Methuen, London. 613 pp.

The first volume of this two-volume work explains the present-day world distribution of climates and provides a skeleton reference of facts and figures for comparison. This understanding of the present day provides a basis from which one can proceed to examine and discuss the differences that are found to have characterized other climatic epochs. Most of the book is concerned with the causation of climate, with discussion of radiation and heat balance, the global circulation, seasonal changes, the stratosphere, cyclic and quasi-periodic phenomena, the oceans and the water balance. There are also chapters on anomalous patterns of atmospheric circulation and some observed causes of climatic variation. The final chapter describes present world climate with world maps of particular variables, discussion of Köppen's climatic classification and a table of monthly and other values, where possible for 1851-1950 for 236 stations.

G.A.

481. LAMB, H.H. 1977. Climate: Present, Past and Future. Volume 2. Climatic History and the Future. Methuen, London. 836 pp.

A compilation and discussion of sources of proxy data including meteorology and para-meteorological phenomena, dating methods, field evidence of past climates interpreted by physical science, the same for biological sciences, and finally evidence from human history and archaeology. This evidence is reviewed over decreasing time-scales: the whole of earth history (with concentration on Triassic to Tertiary times), the Quaternary ice age/interglacial fluctuations, postglacial times, historical times, and finally the period since instrumental records began. This Part III,(pp. 21-654 of this volume) is concluded by 100 pp. of tabulated supplementary data. Part IV discusses man-made climatic changes and the problem of long-range forecasting, with a summary of 24 scientifically-based forecasting systems. References are arranged by chapters (and sub-sections for one chapter) and total over 1500.

G.A.

482. LAMB. H.H., R.P.W. LEWIS, and A. WOODROFFE. 1966. Atmospheric circulation and the main climatic variables between 8000 and 0 B.C.; meteorological evidence. In: International Symposium on World Climate, 8000-0 B.C. Proceedings. pp. 174-217.

Analyzes paleobiological and meteorological evidence for changes in temperature, precipitation and atmospheric circulation during this period. Maps show climatic conditions ca 6500 BC, 4000 BC, 2000 BC and 500 BC with extent of continental glaciers and tree limits indicated. Atmospheric thickness values for these dates, computed from the available evidence, are mapped. Isobaric patterns are also plotted for the Arctic and sub-Arctic, both for January and July, for each date. A sequence of meteorological variations based on these maps is postulated. A bibliography is included.

A.B.

483. LAMB, H.H., and A. WOODROFFE. 1970. Atmospheric circulation during the last Ice Age. Quaternary Research 1(1):29-58.

The prevailing surface temperatures in summer and winter at several different stages of the last ice age, indicated at various points scattered over the Northern Hemisphere, by botanical, glaciological, marine biological, oceanographic, etc. evidence, are used to derive probable distributions of 1000-500 mbar thickness, roughly equivalent to mean temperature of the lowest 5 km of the atmosphere and indicating the general flow pattern of the atmosphere in depth. From these thermal wind patterns, computation of the tendency to cyclonic and anticyclonic development is possible. Maps of this development field, taken together with the indicated steering of surface cyclones and anticyclones by the thermal winds, make it possible to sketch probable distributions of surface pressure (and, by implication, surface winds) prevailing during each of the glacial stages studied. New light is thrown on the onset of glaciation and on the regimes associated with the maximum extent of glaciation, with the Alleröd warm epoch and the Post-Alleröd cold stage when there was some readvance of the ice.

A.A.

484. LARSEN, J.A., and R.G. BARRY. 1974. Paleoclimatology. In: Arctic and Alpine Environments. Edited by: J.D. Ives and R.G. Barry. Methuen, London. pp. 253-276.

Recurring ice ages have persisted for 5-10% of geological time. Climate characteristics have not been constant since the end of the last ice age. The Arctic Ocean was not a factor in the growth or melting of Pleistocene continental glaciers. Theoretical evidence exists for three possible causes of climatic change. Radiation changes and ocean-atmosphere interactions are favoured. Recent circulation changes have implications for future climatic changes. Continual reassessment of existing synthesis is essential.

G.A.

485. LASALLE, P. 1966. Late Quaternary vegetation and glacial history in the St. Lawrence Lowlands, Canada. Leidse Geologische Mededélingen 38:91-128.

This paper presents data of various kinds concerning the Quaternary geology of the St. Lawrence Lowlands: pollen diagrams, C^{14} dates, and diatom floras. These data show that the highest parts of the St. Lawrence Lowlands were already deglaciated more than 12,000 years ago, as appears from the existence of glacial lakes around some of the Monteregian Hills.

The collected evidence seems to confirm the data concerning the age of the Champlain Sea: it lasted from approximately 11,400 years B.P. to somewhat before 9,500 years B.P.

The data supply also evidence for a lowering of sea level during the Champlain Sea episode, related to the St. Narcisse readvance, followed by a sea level rise (indicated by deeper water) after the retreat of the St. Narcisse ice.

As to the pollen diagrams presented here, they show that the New England pollen zonation can be applied to the lacustrine pollen sequence of the St. Lawrence Lowlands, and strongly suggest (together with C^{14} dates) that a correlation exists between the Younger Dryas of northwestern Europe, the St. Narcisse readvance, and the first part of the pollen zone A4 from New England as described by Davis and other workers.

The diatom data of Lake Hertel appear to confirm the present elevation of the maximum marine limit level in the Montreal area as being approximately 570 feet or 171 meters. Finally the diatom floras supply information on the paleoecological conditions of the lakes studied.

A.A.

486. LASALLE, P., and J.A. ELSON. 1975. Emplacement of the St. Narcisse moraine as a climatic event in eastern Canada. Quaternary Research 5(4):621-625.

The length (more than 300 km) and size of the St. Narcisse morainic system suggest that it represents an important glacial event, probably climatically controlled and not related to a surge. Dates on marine materials (shells) both from within and external to the moraine suggest that its time of emplacement was roughly 11,000 years ago, well after the beginning of the Champlain Sea Episode, but still possibly correlative with the Valders event of the Lake Michigan area.

A.A.

487. LASALLE, P., G. MARTINEAU, and L. CHAUVIN. 1979. Lits de bryophytes du Wisconsin moyen, Vallée-Jonction, Québec. Canadian Journal of Earth Sciences 16(3):593-598.

A shallow-water bryophyte arctic to subarctic assemblage, collected in what appears to be shallow-water lake sediments, has been dated at greater than 39,000 ^{14}C years BP(QU-327). It is probably correlative with the Massawipi (St. Pierre) formation.

A.A.

488. LAST, W.M., and J.T. TELLER. 1979. Holocene and late Pleistocene sedimentation history of Lake Manitoba, Canada. Geological Society of America, Abstracts with Programs 11(5):234.

Lake Manitoba, a remnant of glacial Lake Agassiz, contains more than 13 m of lacustrine sediment in its main south basin. Cores of this sediment record are composed dominantly of silty clay and clayey silt except toward the extreme southern end of the basin where less clayey and more sandy units are common. The clay content, quartz, feldspar and dolomite, as well as K, Na, Fe, and Mg, show a general increase with depth in the cores, while silt, moisture content, organic matter, calcite, total carbonates, and Ca decrease with depth. Within this sequence there are three distinctive marker zones at 4500-6000, 7500-8500, and 9500-10,500 years BP. These zones are characterized by a blocky to pelletal structure, contrasting color, and a comparatively low moisture content. In some cases, they exhibit significant changes in organic matter, carbonate content, and clay mineralogy.

We suggest that these marker zones represent episodes of low water when either (1) seasonal or periodic drying dessiccated the lake floor and induced the pedogenic-like structure, or (2) complete winter freezing of the reduced-lake volume caused dehydration of the near-surface mud and development of the blocky structure.

The changes recorded in the postglacial record of Lake Manitoba reflect an interplay of the following variables: (1) areal extent of the lake; (2) watershed size; (3) climatic changes; (4) diversion of the old Assiniboine River; and (5) surface stability of the watershed in relation to source materials.

A.A.

489. LEGGAT, K.R., B.L. MAGILL, N. VAN WASS, and H.S. SANDHU. 1981. The impacts of climate change and variability on Alberta's resources and environment. In: Climate Change Seminar Proceedings. Regina, March 17-19. Canadian Climate Centre, Downsview. pp. 12-25.

"Historical records appear to indicate that Alberta is subject to a greater degree of variability than the rest of Canada. As climate aberrations may exert significant impacts upon resources and the environment, it is necessary to investigate the potential impacts of climate fluctuations, and equally as important, man's role in changing the climate. Through these investigations, planning and management strategies may be formulated for the beneficial development and use of Alberta's resources and environment."

The authors discuss the formation and growth of the Alberta Climatological Association and its activities. The report highlights, by sector, environmental impacts of climate fluctuations; these sectors include agriculture, air, fish and wildlife, forestry, water and others. Improved data bases, improved weatherproofing and improved forecasting are the three areas identified as high priority for "counteracting the impacts of climate fluctuations in Alberta".

A.B.S.

490. LEWIS, C.F.M., T.W. ANDERSON, and A.A. BERTI. 1966. Geological and palynological studies of Early Lake Erie deposits. Proceedings of the Ninth Conference on Great Lakes Research, University of Michigan, Great Lakes Research Division, Publication 15:176-191.

Coring and echosounding of Lake Erie bottom sediments have indicated a thin lag concentrate of sand, in places with plant detritus, pelecypods, gastropods and other fossils, underlying Recent silty clay muds and overlying clay till or late-glacial lacustrine clays. Buried shallow pond organic sediments in the western basin and relict beach deposits, wave-cut terraces and intrabasinal discharge channels in the central basin, some of which are buried, all indicate former low water levels in central and western Lake Erie much below those at present. This evidence, combined with radiocarbon dates of 10,200 and 11,300 years B.P. on the organic material and information from nearby regions, suggests that Early Lake Erie came into existence about 12,400 years ago, with water levels, 100 ft (30 m) lower than at present, at approximately 470 ft above sea level. From this stage lake levels rose rapidly as the outlet area at Buffalo, N.Y., was uplifted isostatically following deglaciation, and probably reached their present elevation 9,000 to 10,000 years ago.

Examination of the cores indicated that pollen is sufficiently abundant and well preserved in the sediments for palynological studies. Pollen diagrams can be correlated with one another and with those outside of the Lake Erie basin. The presence of a legible pollen record indicates that sedimentation has been probably continuous and undisturbed at the sites investigated since low-level Early Lake Erie. Palynological studies support the geological evidence of a low lake stage and provide a means for dating and correlating sediment sequences which do not contain enough organic matter for radiocarbon analysis.

A.A.

491. **LICHTI-FEDEROVICH, S. 1970. The pollen stratigraphy of a dated section of Late Pleistocene lake sediment from central Alberta. Canadian Journal of Earth Sciences 7(3):938-945.**

A 5.5 m section of limnic sediment from Lofty Lake in the Mixedwood Section of the Boreal Forest in central Alberta has yielded the first complete Late Pleistocene pollen stratigraphy for the province. The basal organic sediment was radiocarbon dated at 11400 ± 190 yr (GSC-1049) and a layer of Mount Mazama type ash was recognized at the 398 cm level. This represents the furthest extension into Canada of Mazama ash records. Five pollen assemblage zones have been identified - at the base, a *Populus-Salix-Shepherdia-Artemisia* assemblage, which is unique in the Late Pleistocene of N. America, and is interpreted as a pioneer forest and shrub community which occupied the area immediately following deglaciation. This is succeeded by a spruce dominated assemblage which conforms in general to many early Late Pleistocene *Picea* assemblages from western Canada and adjacent United States, interpreted as a pioneering version of the boreal forest. There follows a tree birch dominated assemblage with poplar and hazel, suggesting a slight amelioration of climate, and this trend appears to have continued to about 6000 B.P. when a birch-alder-herb assemblage reaches its maximum; this is followed by a spruce-birch-alder assemblage, which continued to the present and is interpreted as an expression of a deterioration in climate about 3500 BP. The apparent absence at the site of grassland, although the birch-alder-herb assemblage suggests that the grassland might have advanced closer to the site than at present (240 km (150 miles)), supports the hypothesis that there was never a Late Pleistocene connection between the Peace River and the main southern grasslands.

A.A.

492. **LICHTI-FEDEROVICH, S. 1972. Pollen stratigraphy of a sediment core from Alpen Siding Lake, Alberta. Geological Survey of Canada Paper 72-1B:113-115.**

The pollen stratigraphy of a sediment core recovered from Alpen Siding Lake, Alberta has been determined. Marly gyttja from the base of the core provided a date of 10,700 ± 170 years B.P. (GSC-1093), obtained through ^{14}C dating. "The reconstruction of the vegetation and paleoecological inferences to be drawn from this section are similar to those reported for the Lofty Lake site. A pioneer poplar-shrub community is followed, successively, by a spruce forest (the pollen assemblage being similar to those recorded widely from equivalent Late Pleistocene sediments in the Western Interior of the continent), a birch forest community with poplar and hazel, a birch-alder-herb community, and finally a mixed spruce-birch-pine forest which has persisted to the present day."

A.B.S.

493. LICHTI-FEDEROVICH, S. 1973. Palynology of six sections of Late Quaternary sediments from the Old Crow River, Yukon Territory. Canadian Journal of Botany 51(3):553-564.

The Old Crow Plain, northern Yukon Territory, Canada, is a large flat lowland consisting of basin-fill sediments of Late Quaternary age. The modern Arctic treeline passes across the northern tip of the lowland, and much of the vegetation consists of tundra and shrub tundra, with scattered groves of spruce mainly on alluvial deposits. Steep scarps have been exposed by the downcutting of the Old Crow River in these basin-fill sediments, and good exposures of Late Quaternary sediments are available for investigation. Samples from six of these exposures were analyzed for pollen. Although many parts of the sections were barren, it has been possible to derive pollen diagrams with discrete pollen zones for the six sections, and four pollen assemblage types have been identified. Their occurrence in the stratigraphic sequence suggests the following pattern of pollen stratigraphy; the lowermost sedimentary units, probably deposited early in the interstadial following an Early Wisconsin glaciation, are of pollen assemblage types III (Glumiflorae-herb) or IV (*Betula*-herb), both indicative of tundra vegetation; the middle levels of the sediment show, consistently, pollen spectra of type II (*Picea-Betula*-Glumiflorae-herb), indicating forest groves with tundra, quite similar to the modern vegetation. The sediment underlying the Upper Glaciolacustrine Unit (correlative, according to Hughes (1969), with the Classical Wisconsin Stadial) yields pollen assemblage type III (Glumiflorae-herb), which is interpreted as indicating a rich and varied tundra. These vegetation reconstructions are consonant with a tentative paleoclimatic interpretation in terms of a tripartite interstadial climate showing severe tundra climate - milder forest or forest-tundra climate - severe tundra climate. Two of the sections have incomplete pollen stratigraphy for the uppermost postglacial silts and peats. They suggest that vegetation similar to the present day became established in the Old Crow Plain in mid-postglacial time.

A.A.

494. LICHTI-FEDEROVICH, S. 1974. *Najas guadalupensis* (Spreng.) Morong. in the Missinaibi Formation, northern Ontario. Geological Survey of Canada Paper 74-1:201.

A noteworthy paleofloristic record was made during megafossil analysis of peat samples collected from the Missinaibi Formation by R.G. Skinner, Geological Survey of Canada, in 1972. These beds of interglacial peat and silt (Skinner, 1973) occur at Moose River Crossing (50°19'N, 81°18'W) in northern Ontario within the James Bay lowlands. A total of 20 seeds of *Najas guadalupensis* (Spreng.) Morong. was recorded from peat samples. A complete report of the megafossil analysis and pollen stratigraphy of this material will be published separately.

This record of *Najas guadalupensis* is notable because of the paleofloristic implications.

The occurrence of this species of southern affinity in an assemblage of plants of distinctly boreal-northern provenance is of interest. The species has not been recorded previously in pre-Wisconsin sediments of Canada, although it has been found by Gruger (1972) in sediments of Farmdalian and older age in south-central Illinois.

The most likely explanation for the apparent anomaly of its association with species of different floristic and ecological affinity is that it occurred at this site during some non-glacial late-Quaternary episode as a northern ecotype which has either not been recorded so far in modern communities or has not persisted to the present day.

Excerpts

495. LICHTI-FEDEROVICH, S. 1974. Palynology of two sections of late Quaternary sediments from the Porcupine River, Yukon Territory. Geological Survey of Canada Paper 74-23:1-6.

Two exposures of Quaternary sediments along the Porcupine River, northern Yukon Territory, were sampled. The upper part of the pollen and sediment stratigraphic record shows a close correlation with results from the Old Crow Flats area. Two glacio-lacustrine units are correlative with the Classical Wisconsin and the lower with an older glacial stage.

The sediments underlying the Lower Glacio-lacustrine Unit yield a pollen assemblage distinct from any occurring in younger strata. This assemblage is distinguished by the occurrence of pine and hazel pollen, associated with tree birch, alder and spruce. Subzones with and without hazel are recognized. The assemblage is interpreted as indicating the presence of a forest dominated by spruce and birch with some pine also present. The upper pollen zones are characterized by pollen assemblage types identical to those of the Old Crow area, which were interpreted as representing a transition from arctic tundra through boreal forest to subarctic or arctic tundra.

A.A.

496. LICHTI-FEDEROVICH, S. 1975. Pollen analysis of ice core samples from the Devon Island ice cap. Geological Survey of Canada Paper 75-1A:441-443.

Samples dated at 2900-3000 yrs B.P.; 6000-8000 yrs B.P. and 12,000-50,000 yrs B.P. were collected. The spectra from all levels are dominated by pollen from distant sources. They correlate with parts of the pollen stratigraphy which has been developed for the western Low Arctic of North America (Hopkins, 1972; Ritchie, 1972). The near absence of pine suggests a western origin; this is concordant with modern air mass circulation in the Arctic (Hare and Hay, 1974).

L.G.

497. LICHTI-FEDEROVICH, S. 1975. Pollen analysis of surface snow from five Canadian Arctic ice caps. Geological Survey of Canada Paper 75-1B:135-137.

Pollen and spore totals from snow samples of five Arctic Island ice caps are presented; the totals are small and have limited interpretive value. Nevertheless, a common feature is the preponderance of exotic types, with origins in boreal and temperate regions.

L.G.

498. Life, Land and Water. Edited by: W.J. Mayer-Oakes. Proceedings of the 1966 Conference on Environmental Studies of the Glacial Lake Agassiz Region, University of Manitoba Press, Winnipeg. Department of Anthropology, University of Manitoba Occasional Paper No. 1:1-414. 1967.

Glacial Lake Agassiz is a subject that can only be addressed effectively through interdisciplinary study. This volume contains such studies. Relevant papers to this bibliography have been annotated individually.

A.B.S.

499. LINDSEY, C.C. 1978. Aquatic zoogeography and the Ice-free Corridor. American Quaternary Association, National Conference, Abstracts 5:31-34.

Unlike botanical evidence, the paleontology of fish has contributed little to reconstruction of the Quaternary climate and events in the Ice-free Corridor. Quaternary fossil fish finds are Arctic Grayling and Northern Pike, both from Late Pleistocene deposits near Old Crow (McAllister and Harington, 1969; Crossman and Harington, 1970). Both species are currently widespread, ranging from the Arctic coast to south of 50°N in North America and in Eurasia. Probably each survived in both the Beringian and Mississippian refugia, judging from present distributions and from suggestion of slightly different morphological types among survivors in the two areas (McPhail and Lindsey, 1970).

The presence or absence of certain aquatic species in lakes in or near the Ice-free Corridor in NWT and YT indicate that some drainage patterns have been drastically altered by glacial maxima.

In summary, the northern samples support the possibility of a much more extensive temporary Yukon River drainage than has been suspected. That drainage could conceivably have had its source at or even south of the northern Alberta border, but its southern limit, and the contribution of endemic forms from within the Ice-free Corridor, cannot be identified without sampling more key lakes.

Evidence about palaeoecological conditions in water bodies in the Corridor is only available from modern distributions in special circumstances. In certain isolated lakes (e.g. Margaret L., YT) a distinct fish population persists which evidently originated from a drainage not now connected to that lake. This is evidence that climate has been continuously tolerable to that species since the disconnection of the drainage, i.e. there has been open water on the lake each summer, and temperature has never risen above acceptable limits. Unfortunately, ancient lakes in the Corridor have often filled in and enriched so that now no fish persist, probably due to winter anoxia under ice-cover. Here only zooplankton species offer historical evidence, but this is less reliable due to uncertainty as to the time of entry to the lake (birds' feet, wind drift etc.?). Greatest promise lies with increasingly sensitive biochemical methods to detect distinctive genotypes in geographically isolated fish populations.

pA.A.

500. LIU, K.B. 1980. Pollen evidence of late-Quaternary climatic changes in Canada; a review; Part 1, Western Canada. Ontario Geographer 15:83-101.

The occurrence and timing of the Hypsithermal is a major problem of palynological research in western Canada. Evidence for a mid-postglacial warm (and dry) interval has been well documented for sites close to the forest/prairie ecotone, where change from an early *Picea*-dominated assemblage to a NAP-dominated assemblage in the pollen diagrams has been interpreted as a northward expansion of the prairie into spruce forest (Ritchie, 1976). Pollen and megafossil/paleosol evidences for a mid-postglacial advance of the arctic treeline have also been documented from the Tuktoyaktuk Peninsula (Ritchie and Hare, 1971) and Keewatin (Bryson *et al.*, 1965; Nichols, 1967a). But in areas farther away from ecotones, changes in the pollen diagrams are less distinct and their interpretation is complicated by the differential migration of species, such as *Picea, Alnus* and *Pinus* in the northwest and *Pinus* and *Quercus* in the southeast of the study region (e.g. Miller and Anderson, 1974; Rampton, 1971; Ritchie, 1976, 1977). On the other hand, a mid-postglacial warm interval is not evident from the pollen record in coastal British Columbia, probably as a result of oceanic influence. These results echo the theoretic problems discussed in an earlier section of this paper, that the usefulness of pollen analysis in paleoclimatic reconstruction is site-dependent, being more sensitive in ecologically stressed environments than in areas far from ecotones. The role played by nonclimatic factors (e.g. differential migration, differential pollen representation, etc.) should be adequately considered in any paleoclimatic reconstruction based on pollen data.

A.S.

501. LIVINGSTONE, D.A. 1968. Some interstadial and postglacial pollen diagrams from eastern Canada. Ecological Monographs 38(2):87-125.

The author presents pollen diagrams of one postglacial section from Gaspé Peninsula and of one interstadial and six postglacial sections from Nova Scotia.

The interstadial deposit from western Cape Breton Island, Nova Scotia, has an age of over 38,000 years. Two pollen zones were revealed, the lower characterized by high values of alder pollen, the upper by spruce pollen. The author notes no similarity to any postglacial zone from Nova Scotia.

The analysis of seven postglacial lake deposits revealed three herbaceous pollen zones, L-1, L-2, L-3, so far found only at one locality in eastern Canada. The author suggests that those sites presenting the incomplete upper part of this three-zone record of a climatic oscillation were uncovered by retreating glacier ice at successively later times. In most localities three arboreal pollen zones, A, B, C, could be distinguished above the herbaceous zones. Spectra contained in the A zone at Gaspé suggests the climate was not as warm as present. Zone C was divisible into three subzones at all localities; the spectra contained in C-2 zones from the Gaspé and Nova Scotia sites suggest a slight cooling of climate since the end of C-2 time.

A.B.S.

502. LIVINGSTONE, D.A., and A.H. ESTES. 1967. A carbon-dated pollen diagram from the Cape Breton Plateau, Nova Scotia. Canadian Journal of Botany 45(3):339-359.

Organic sedimentation in a lake near the southwestern edge of the Cape Breton Plateau began about 9000 years ago. Before that time the vegetation was an open tundra, probably with scattered conifer and poplar trees. Since then the vegetation has been dominated by closed fir forest of a variety of types not dissimilar to forests growing in various parts of Nova Scotia today. Organic sedimentation and the establishment of forest, and by implication deglaciation, began more recently at Wreck Cove Lake than at any other Nova Scotian locality that has been investigated. The establishment of forest occurred 1300 years sooner in part of lowland Cape Breton, and 1800 years sooner in part of mainland Nova Scotia, than it did on the Cape Breton Plateau. The length of postglacial, preforest time, which cannot be measured by radiocarbon dating appears to have been much shorter at Wreck Cove than it was in lowland Cape Breton. The Cape Breton Plateau was not, as some phytogeographers have suggested, a nunatak during glacial time. It may have been a center of late-glacial readvance.

A.A.

503. LIVINGSTONE, D.A., and B.G.R. LIVINGSTONE. 1958. Late-glacial and postglacial vegetation from Gillis Lake in Richmond County, Cape Breton Island, Nova Scotia. American Journal of Science 256 (5):341-359.

Pollen analysis of a deposit from Gillis Lake, Richmond County, Nova Scotia, has yielded a stratigraphy consisting of nine zones, two of which are tentatively divided into sub-zones. The three bottom zones are characterized by the pollen of open vegetation, particularly of heaths, willow, sedges, grasses and *Artemisia*. The second of these three zones contains more shrub pollen than the other two, and appears to represent a transitory warm time corresponding to the Two Creeks interval. The upper limit of these late-glacial zones has been carbon-dated at 10,340 ± 220 years, which suggests that this part of Nova Scotia was deglaciated shortly before Two Creeks time and has been ice-free since. The amount of coniferous pollen in the late-glacial zones suggests that the vegetation was not completely open, but the presence of tree species immediately after deglaciation has not been definitely established. The vegetation was certainly open enough to permit much wider ranges of a number of plants now restricted to isolated bare-ground habitats, including, by inference, many of the Cordilleran disjunct species. *Ulmus*, a genus whose native status in Nova Scotia has been in doubt, has been part of the vegetation since the entry of mixed deciduous forest, and *Artemisia* have been intermittently present during postglacial time. The influence of European settlement on the vegetation is clearly shown in the top sub-zone of the profile.

A.A.

504. LOCKE, C.W., and W.W. LOCKE, III. 1977. Little Ice Age snow-cover extent and paleoglaciation thresholds: north-central Baffin Island, N.W.T., Canada. Arctic and Alpine Research 9(3):291-300.

On air photographs, light-colored areas representing reduced lichen cover indicate the maximum extent of permanent snow cover in the recent past. Lichen-free areas were mapped on 1:50,000, 1:250,000, and 1:1,000,000 map sheets of north-central Baffin Island using air photographs and LANDSAT-1 satellite imagery. Present ice and lakes cover 37% of the study area (97,000 km^2). During the Little Ice Age (350 to 100 yr BP), ice and lakes covered about 50% of the study area - an increase of 35%. The amount of lichen-free area is greatest in the elevational range of 450 to 600 m a.s.l.

A limited amount of lichenometrical measurements indicate that the lichen-free areas probably represent a period of more extensive snow cover approximately synchronous with the Little Ice Age.

Paleoglaciation thresholds and paleoequilibrium-line altitudes increased in elevation toward the northeast with lowest elevations southwest of the Barnes Ice Cap. Paleoglaciation thresholds ranged from 500 to 850 m a.s.l. whereas paleoequilibrium line altitudes ranged from 300 to 900 m a.s.l. Present glaciation thresholds and equilibrium-line altitudes ranged from approximately 100 to 400 m higher than the paleovalues. The difference between present and paleovalues is greatest over the mountainous east coast and decreases to the west.

A.A.

505 LOCKE, W.W., III. 1979. Etching of hornblende grains in Arctic soils: an indicator of relative age and paleoclimate. Quaternary Research 11(2):197-212.

The degree of etching of hornblende grains in soils is defined as the mean depth of maximum etching on 100 grains per sample and is a function of: (1) the depth in the profile; (2) the age of the deposit on which the soil is formed; and (3) the climate since deposition. In soils formed on moraines in the eastern Canadian Arctic, etching decreases logarithmically with increasing age. The most important climatic parameter with respect to etching appears to be the effective precipitation. Equally important in terms of soil moisture regimen is the presence of unfrozen water. Both affect the rate of etching as a function of depth and age.

For Cumberland Peninsula, Baffin Island, N.W.T., Canada, this technique allows a climatic reconstruction as follows: (1) a warm wet period preceded the last glaciation; (2) a mild moist period occurred between ca. 100,000 and 60,000 yr B.P.; (3) extreme aridity and/or cold prevailed between ca. 60,000 and 8000 yr B.P.; (4) a mild moist climate returned between ca. 8000 and 3200 yr B.P.; and (5) cool dry conditions occurred between ca. 3200 yr B.P.; and the present.

Part of the climatic reconstruction is corroborated by etching in cryoturbated soils. Comparisons with stable soils indicate that the surface soils began to form ca. 4000 yr B.P. on previously frost-stirred terrain. These data are concordant with the onset of cool dry conditions as determined above.

A.A.$^+$

506. LOEWE, F. 1971. Considerations on the origin of the Quaternary ice sheet of North America. Arctic and Alpine Research 3(4):331-344.

It is generally agreed that the Quaternary ice sheets of the Northern Hemisphere were brought about by a cooling of the atmosphere. A temperature decrease tends to reduce water vapor in the air and thus the precipitation. Ahlmann's curve connecting summer temperature and apparent accumulation at the glaciation limit is probably not applicable to the start of the Labrador-Ungava ice sheet which could have been initiated with smaller accumulation than the curve indicates. However, a cooling of 6°C with the present precipitation hardly seems sufficient. It is unlikely that "glacial ice" of high density could have started an ice sheet itself. Even if the possibility of a growth of the Keewatin ice sheet from "valley ice" is accepted, a cooling of only 6°C would not be enough. The region would then have had the climate of unglacierized northern Siberia today. The start of the North American ice sheet would have required an initial cooling considerably greater than 6°C, or a decrease of 6°C with precipitation somewhat higher than the present. The condition which brought about the synoptic and climatic changes which started the Quaternary ice sheet of North America are still not established.

A.A.

507. LØKEN, O.H. 1965. Postglacial emergence at the south end of Inugsuin Fiord, Baffin Island, N.W.T. Geographical Bulletin 7(3-4):243-258.

A beach deposit from Inugsuin Fiord, Baffin Island, is described and its mode of formation outlined. It was possible to relate a number of shell samples to the sea levels prevailing when the shells lived. An accurate emergence curve has been drawn which is similar in form to curves obtained from other areas. The early part of postglacial time was characterized by a rate of emergence much smaller than observed in other areas and there are distinct differences between the pattern of emergence on the west and the east coasts of Baffin Island.

A pronounced bench on the beach deposit is discussed and is believed to be associated with a postglacial halt in the process of emergence. This is possibly a parallel to a postglacial transgression in northern Labrador and of late Tapes age. Fossil evidence suggests a climate in early postglacial time warmer than the present.

A.A.

508. LONGLEY, R.W. 1953. Temperature trends in Canada. Royal Meteorological Society. Proceedings of the Meteorological Conference, Toronto. pp. 207-211.

The author used data from 50 to 60 locations across the country and grouped the stations into fourteen regions for the preparation of ten year running means. He found that in every district in which records went back to 1880, the decade of the '80s was cold. The absolute minimum occurred during the decade 1879-1888. He took 1903 as the end of the universal cold spell and showed that immediately thereafter there were only minor fluctuations and none which were found in all districts. In Eastern Canada the period 1903-1926 is marked by a slow falling temperature in some regions, and the period 1926-1952 saw a general rise in temperature although in many districts a reversal was in evidence between 1939 and 1943. Northern Ontario was the only eastern district for which the decade ending in 1952 was not the warmest on record. In western Canada the trend for the past ten years is decidedly different. 1946-47 saw the end of the very warm decades and in all districts these were the warmest or very nearly the warmest decades on record. The succeeding five years saw mean temperatures drop, and in Alberta the decade ending in 1951 was the coldest since 1904. During the past 10 years the line of demarcation between the cooling of the west and the warming of the east is not well defined, but is located in northwestern Ontario. In British Columbia there was a cold period around 1920, a warming period in the early 1930s, a short drop until 1937 and rising until the mid '40s. The data for northwestern Canada show many of these same fluctuations. Evidently, the factors controlling temperature fluctuations in British Columbia influence the Yukon and the Mackenzie River Valley much more than they do the Prairie Provinces. The Northeast Arctic, Hudson Strait temperatures have apparently followed those of eastern Canada. In conclusion, the author states that the spatial as well as the temporal extent of the temperature fluctuations have been seen to be quite variable. Some changes are gradual, and others such as the recent drop in western Canada are abrupt. Some changes are general and others local. For example, the drop in temperature near 1920 was limited to British Columbia.

Thomas

509. LONGLEY, R.W. 1954. Mean annual temperatures and running mean temperatures for selected Canadian stations. Department of Transport, Meteorological Division CIR.-2481, TEC.-186:1-45.

Annual and ten year running mean annual temperatures are listed year by year for 62 Canadian stations from the beginning of record to 1952. Another table shows ten year running mean annual temperatures by districts. This circular contains the basic data used in the preparation of the paper "Temperature Trends in Canada".

Thomas

510. LOUBERE, P. 1982. Plankton ecology and the paleoceanographic-climatic record. Quaternary Research 17(3):314-324.

The paleoceanographic-climatic record represented by deep-sea microfossils reflects conditions for only certain times of the year. Also, the relative abundances of microfossil species in deep-sea sediments do not usually reflect only one paleoceanographic variable, such as temperature. Rather, species distributions represent the integration of many factors that control biological production in the oceans. This influences the information on past climates that can be extracted from fossil material. The seasonal limitation is due to the cyclic nature of biological production in the open ocean. Case studies of the sediment record in the Atlantic for two species of planktonic Foraminifera, left-coiling *Neogloboquadrina pachyderma* (Ehrenberg) and *Globigerinoides ruber* (d'Orbigny), illustrates seasonal bias in environmental data reported by the relative abundances of species in deep-sea sediments. In addition, the study of *G. ruber* illustrates the operation of two oceanographic parameters in controlling a species distribution. These examples demonstrate that the environmental signal in the sediments is the result of the interplay of the ecological tolerance of the plankton species with seasonally variable biological and physical properties of the upper ocean.

A.A.

511. LÖVE, D. 1959. The postglacial development of the flora of Manitoba: a discussion. Canadian Journal on Botany 37(4):547-585.

An attempt is made to establish the development of the flora of Manitoba, Canada, after the complete extermination by the Wisconsin glacier of any pre-existing vegetation.

Based upon geology, palynology, and floristics, a theory is constructed that the ice was at first followed by a cold (marsh) grassland, covering the bottom of the drained Lake Agassiz I, and a riverine spruce (-pine) parkland of western origin, which persisted throughout the Valders period and the damming up of Lake Agassiz II. Around 9000 B.P. a deciduous forest flora started to fill in around the edges of Lake Agassiz II, and a pine-oak savanna occupied the drier portions of the upland. This flora reached its maximum north- and westwards distribution towards the peak of the Hypsithermal. Also during the Hypsithermal it is suggested that a western (-southwestern) prairie flora covered the bottom of the draining Lake Agassiz II, reaching its farthest extension towards the north and east. During the same time, the Arctic flora expanded over the Hudson's Bay Lowland. The last part to be covered by vegetation seems to have been the zone now called taiga, probably as late as 3000-4000 years ago. The spruce forest and its undervegetation seems to have arrived both from the west and from the east, and in recent times (from 2000 to 3000 B.P.) is in a stage of expansion, forcing itself into the deciduous zone, which in turn is expanding over the prairie, save for the checking activities of Man (fire and cultivation).

A.A.

512. **LÖVE, D. 1962. Plants and Pleistocene. In: Problems of the Pleistocene Epoch and Arctic Area. Volume 2. Compiled by: G.R. Lowther. Publications of McGill University Museums (Montreal), No. 2. pp. 17-39.**

In general it can be said that the Pleistocene Era meant a gradual extinction of the existing floras as well as a zonal re-arrangement of vegetation belts in certain regions during the Ice Ages. In turn each interglacial period allowed a gradual come-back of the vegetation into the devastated areas and a fusion of species which had suffered a split distribution because of the continental ice covers. It seems, however, that each interglacial was long enough for a complete recovery of the flora. During the different interglacials the come-back developed somewhat differently...". [The author demonstrates these re-arrangements by surveying the changes in poppies, particularly *Papaver radicatum.*]

Excerpt+

513. **LOWDEN, J.A., and W. BLAKE, Jr. 1968. Geological Survey of Canada radiocarbon dates. Geological Survey of Canada Paper 68-2B:1-39. (reprinted from Radiocarbon 10:207-245.)**

Title is self-explanatory.

C.R.H.

514. **LOWDEN, J.A., and W. BLAKE, Jr. 1973. Geological Survey of Canada radiocarbon dates. Geological Survey of Canada Paper 73-7:1-61.**

Title is self-explanatory.

C.R.H.

515. **LOWDEN, J.A., J.G. FYLES, and W. BLAKE, Jr. 1967. Geological Survey of Canada radiocarbon dates. Geological Survey of Canada Paper 67-2B:1-42. (reprinted from Radiocarbon 9:156-197.)**

Title is self-explanatory.

C.R.H.

516. **LOWDEN, J.A., I.M. ROBERTSON, and W. BLAKE, Jr. 1971. Geological Survey of Canada radiocarbon dates. Geological Survey of Canada Paper 71-7:1-69. (reprinted from Radiocarbon 13(2):255-324.)**

Title is self-explanatory.

C.R.H.

517. LOWTHER, G.R., compiler. 1959. Problems of the Pleistocene Epoch and Arctic Area. Publications of McGill University Museums (Montreal), No. 1. 119 pp.

The eight papers included in this volume are a selection from those presented at a seminar in the spring of 1957. The purpose of this selection was to provide a background to Pleistocene and Arctic studies. Papers determined relevant to this bibliography have been annotated separately.

A.B.S.

518. LOWTHER, G.R., compiler. 1962. Problems of the Pleistocene Epoch and Arctic Area. Volume 2. Publications of McGill University Museums (Montreal), No. 2. 67 pp.

The six papers included in this volume are a selection from those presented at a seminar held in the academic year 1958-59. Papers determined relevant to this bibliography have been annotated separately.

A.B.S.

519. LUCKMAN, B.H. 1977. Lichenometric dating of Holocene moraine at Mount Edith Cavell, Jasper, Alberta. Canadian Journal of Earth Sciences 14(8):1809-1822.

A preliminary growth curve for the lichen *Rhizocarpon geographicum* over a 250 year period was determined on moraines of quartzite debris at Mount Edith Cavell and Penstock Creek, Jasper National Park, Alberta. The dating control was obtained by dendrochronology and from documentary and photographic sources. The average growth over this period is 25 mm/century but the curve appears to be exponential in form and can be subdivided into 42 mm/century for the first 110 years and 11.4 mm/century for the subsequent 140 years. The latter figure gives a maximum estimate for the linear phase of *Rhizocarpon geographicum* in this area.

Four "Little Ice Age" moraines are identified and dated as 1705 ± 5, 1720 ± 5, 1858 ± 7, and 1888 ± 7 AD at Mount Edith Cavell, and 1765 ± 5, 1810 ± 5, 1876 ± 5, and 1907 ± 5 AD at Penstock Creek. Recession of Cavell Glacier averaged about 16 m/year from 1927-1963 and 6-8 m/year from 1963-1975. Angel Glacier shows a similar pattern but has maintained its frontal position since 1962. Remnants of at least three "pre-Little Ice Age" moraines occur in two small areas at Mount Edith Cavell. The minimum lichenometric age for the oldest moraine is about 1800 BP. The presence of Bridge River Ash in the soils in front of the 1705 moraine indicates no greater glacial advance in the last 2600 years. Thus although several glacial advances occurred at this site during the Holocene they were of similar or smaller extent than the "Little Ice Age" maximum.

A.A.

520. LUKENS, P.W., Jr. 1967. The Tailrace Bay site fauna. In: Life, Land and Water. Edited by: W.J. Mayer-Oakes. Proceedings of the 1966 Conference on Environmental Studies of the Glacial Lake Agassiz Region. Department of Anthropology, University of Manitoba Occasional Paper 1:313-321.

Comparison of the Grand Rapids archeological fauna with the recent terrestrial fauna of the Manitoba north lowlands suggests no major faunal changes and hence, by inference, no major environmental shifts during the period of human occupation. The obvious faunal differences are recent, the result of extirpation or environmental alteration by the white man. Thus we can tentatively assume that the major habitats in the Grand Rapids area have not changed markedly during the past 4500 years. However, it is likely that vegetational succession has changed the relative proportions of the various habitats. The faunas in turn may be different, but the differences would be in distribution and abundance rather than kind.

Excerpt

521. LUTWICK, L.E. 1969. Identification of phytoliths in soils. In: Pedology and Quaternary Research. Edited by: S. Pawluk. University of Alberta Press, Edmonton. pp. 77-82.

Phytoliths are biogenetic opals formed in mature cells of plants, especially grasses. Some phytoliths have shapes characteristic of the plant species in which they were found. The occurrence of phytoliths in soils provides a fossil record of components of previous vegetation communities that occupied the site under study.

Phytoliths in some buried soils were used to indicate that the soils were of grassland origin. This was supported by evidence from the infrared spectra of the humic acids.

In surface soils of the forest-grassland transition zone, the occurrence of fescue phytoliths indicated the previous occurrence of fescue grasses where aspen trees and reed grasses presently occur. Since the trees can be supported in that climate and since fescue grasses do not tolerate shade, there has been a change in environment, probably the suppression of fire since settlement occurred.

The occurrence of reed-grass phytoliths in cumulic soils of the foothills indicates that such soils were derived from water discharge zones. Overland flow from water recharge zones is probably non-existent or only of minor influence in the colluviation process contributing to the development of these soils.

A.A.

522. LYONS, J.B., and J.E. MIELKE. 1973. Holocene history of a portion of northernmost Ellesmere Island. Arctic 26(4):314-323.

Radiocarbon dates and glaciological features of the Ward Hunt area along northernmost Ellesmere Island suggest the following chronology, which is consistent with world-wide climatic oscillations: 1) 10,000-4100 B.P.: deglaciation, and development of several marine levels, particularly one now 40 m above sea level, at 7500 ± 300 B.P.; 2) 4100-2400 years B.P.: climatic deterioration, glacial readvance and formation of ice shelves; 3) 2400-1400 years B.P.: general climatic amelioration; development of dust ablation horizon on Ward Hunt Ice Sheif, glacial retreat; 4) 1400 B.P.-present: climatic deterioration, with renewed thickening of Ward Hunt Ice Shelf, and beginnings of growth of ice rises; the last-mentioned experienced maximum growth in the interval between 350-170 years ago; slight glacial readvance.

The isostatic rebound curve for northernmost Ellesmere Island differs from that of the Tanquary Fiord area 80 miles (128 km) to the south because of differing Pleistocene ice thicknesses. We estimate these to average at least 600 m for the former area, and 1800 m for the latter.

A.A.

523. MACDONALD, G.M. 1982. Late Quaternary paleoenvironments of the Morley Flats and Kananaskis Valley of southwestern Alberta. Canadian Journal of Earth Sciences 19(1):23-35.

A 3.1 m section of limnic sediment and peat from a bog on the Morley Flats and a 2.8 m section of limnic sediment from Wedge Lake in the Kananaskis Valley have yielded the first comprehensive late Quaternary biostratigraphic record from southwestern Alberta. Both sections were analyzed for subfossil pollen, molluscs, and several sedimentary indices. Two distinct pollen zones were recognized. The basal zone, characterized by high relative abundancy of *Artemisia-Salix-Juniperus*, suggests that the Morley Flats were dominated by a sparse vegetation composed of aggressive pioneer species following deglaciation until prior to approximately 10,000 BP. Similarly, the mollusc fauna from this zone is dominated by northern ranging species. The second zone is typified by a predominance of *Pinus* and *Picea*. This reflects the expansion of coniferous forest into the region. Both the relative abundance of southern ranging mollusc species and the total carbonate concentration in the sediment in-crease in this zone. The vegetation of the region has remained generally stable since at least 9395 BP. However, increases in the abundance of *Pinus* relative to *Picea* and *Abies* in the mid-Holocene suggest that this period experienced an increase in fire frequency, possibly generated by climatic amelioration.

A.A.

524. MACKAY, J.R. 1976. Ice-wedges as indicators of recent climatic change, western Arctic coast. Geological Survey of Canada Paper 76-1A:233-234.

Many active ice wedges along the western Arctic coast have been rejuvenated in response to a thinning of the active layer and upward permafrost aggradation. When the general cooling trend was interrupted by warm periods, the tops of the new ice wedges were truncated, so that subsequent cooling and cracking produced tertiary wedges. The evidence from active ice wedges along the western Arctic coast suggests a thinning of the active layer of about 10 per cent to a maximum of 40 per cent in the recent past.

A.C.

525. MACKAY, J.R. 1978. Freshwater shelled invertebrate indicators of paleoclimate in northwestern Canada during late glacial times: discussion. Canadian Journal of Earth Sciences 15(3):461-462.

The preservation of both icy Pleistocene sediments and the lower portions of relic ice wedges beneath a widespread thaw unconformity within 60 km of site 3 of Delorme *et al.* (1977) suggest a maximum postglacial thaw of only a few metres. Permafrost has then been present, along the western Arctic Coast, throughout postglacial time. Therefore mean annual ground temperatures have not risen above 0°C except for very brief periods measurable only in years not centuries. As present mean annual air temperatures in Canada tend to be several degrees colder than mean annual ground temperatures, it seems probable that mean annual air temperatures were several degrees below 0°C during the postulated warm interval 14 410 - 6820 years BP.

A.C.

526. MACKAY, J.R., and J. TERASMAE. 1963. Pollen diagrams in the Mackenzie Delta area, N.W.T. Arctic 16(4):228-238.

The sequence of postglacial climatic changes, although apparent from the studies made, cannot yet be satisfactorily interpreted from the available evidence. Radiocarbon dates for driftwood in the Ibyuk pingo and [Eskimo Lakes] suggest that the area was icefree 12,000 to 11,000 years ago. Around 8,200 BP the area was probably forested to the same extent as at present. It is also quite possible that postglacial reforestation began much earlier south of the area studied and to the west of it. Evidence for a warmer postglacial climate than the present is widespread [and described in the text].

Indirect evidence for climatic change comes from a study of the ages of the pingos of the Mackenzie Delta area. Most of the 1,400 pingos have a cover of vegetation with an underlying thin peat layer, tundra polygons with ice wedges many feet in width, and a thicker peat deposit is feathering out against the sides; ... the majority are well over a thousand years old. ... For the Mackenzie Delta pingos, a cooling trend for the past few thousand years accompanied by diminishing precipitation would best account for pingo formation.

"The following, decidedly tentative sequence of climatic events is proposed for the Mackenzie Delta area. Deglaciation occurred about 12,000 years ago. Palynological studies indicate a rather cool-dry climate (compared with the present) from 8,500 to 7,500 years ago. This episode was followed by a warmer one with possibly less available moisture and with more rapid decay of peat locally (pollen poorly preserved, peat accumulation slow). A later increase in available moisture has been assumed to be indicated by a maximum of Ericaceae. The maximum of *Myrica* pollen suggests a probable cooling of the climate with a later increase in moisture as shown by an increase of alder and Ericaceae. The abundance of *Sphagnum* spores in the upper part of the Twin Lakes diagram lends support to the assumption of increased available moisture in late postglacial time. A cooling was associated with the formation of many pingos in the past several thousand years."

Excerpt+

527. MACNEISH, R.S. 1962. A discussion of the Recent geology and archaeological sites in the northern and southern Yukon. In: Problems of the Pleistocene Epoch and Arctic Area. Volume 2. Compiled by: G.R. Lowther. Publications of McGill University Museums (Montreal), No. 2. pp. 40-43.

The comparison of these two Yukon sequences reveals a number of similarities that may indicate similar general climatic trends common to all the Yukon during the last part of the Pleistocene and Recent periods. In both areas the climate seems to have been like the present for the last 2,000 years. From 2 to 4,000 years ago both areas had the same somewhat cooler period. The pink soils of the south Yukon and the humic soils of the Firth River seem to represent a warm dry period - perhaps the post-glacial optimum from 4,000 to 7,000 years ago. At this point in our sequences the similarities cease. The Yukon coast had a cold-wet period of glacial conditions. On the other hand, the southwest Yukon had a cold-dry period, preceded by glacial conditions.

Excerpt

528. MACNEISH, R.S. 1964. Archaeological excavations, comparisons and speculations. In: Investigation in Southwest Yukon. Phillips Academy, Robert S. Peabody Foundation for Archaeology, Andover, Massachusetts. Paper 6.6(1-2):201-488.

Correlates the Lake Kluane-Dezadeash-upper Yukon River culture sequences of traditions in the American Northwest and east Asia: distribution of common traits are tabulated and movements across the Bering Strait area traced. The occupation history of five stratified sites in southwest Yukon is described, cultural components considered, and seven sequential phases identified. Kluane, the oldest complex is dated about 8,000 BC, i.e. coeval with grassland and tundra vegetation. The fifth or Taye Lake phase of about 500 BC corresponded to the period of extensive forestation. Excavated artifacts and osteological materials, also the prehistoric to recent settlement patterns are treated in appendix.

A.B.

529. MACPHERSON, J.B. 1981. The development of the vegetation of Newfoundland and climatic change during the Holocene. In: The Natural Environment of Newfoundland, Past and Present. Edited by: A.G. and J.B. Macpherson. Department of Geography, Memorial University of Newfoundland, St. John's. pp. 189-217.

The core of this chapter, consists of a series of maps dealing with representative random pollen spectra and vegetation boundaries, and pollen spectra maps for the periods 10,000, 9,000, 8,000, 7,000, 6,000, 5,000, 4,000 and 2,000 B.P. In the latter maps, pollen spectra are shown in pie diagrams for each site, the diagrams being divided according to relative percentages of the following types: tundra, shrub, birch, boreal trees and temperate trees. Fifty-seven references are given.

The author suggests a changing sequence of dominant controls upon the climate of Newfoundland and Labrador during the Holocene. First, residual ice over Labrador acted as a source of arctic air, and fewer frontal systems than at present would have passed over Newfoundland. As ice disappeared, and warming occurred to the south, the equivalent of the Bermuda High affected the Maritime Provinces, and possibly also southern Newfoundland, in summer, while weak frontal systems passed over Labrador and Baffin Island. As atmospheric temperatures began to decline, the North Atlantic remained warm, and vigorous cyclonic activity affected eastern Canada. Reduction in ocean surface temperatures has been associated with a regional climatic deterioration since 3,000 B.P.

C.R.H.

530. MADDEN, R.A., and V. RAMANATHAN. 1980. Detecting climate change due to increasing carbon dioxide. Science 209(4458):763-768.

The observed interannual variability of temperature at 60°N has been investigated. The results indicate that the surface warming due to increased carbon dioxide which is predicted by three-dimensional climate models should be detectable now. It is not, possibly because the predicted warming is being delayed more than a decade by ocean thermal inertia, or because there is a compensating cooling due to other factors. Further consideration of the uncertainties in model predictions and of the likely delays introduced by ocean thermal inertia extends the range of time for the detection of warming, if it occurs, to the year 2000. The effects of increasing carbon dioxide should be looked for in several variables simultaneously in order to minimize the ambiguities that could result from unrecognized compensating cooling.

A.S.

531. MAHER, W.J. 1968. Muskox bone of possible Wisconsin age from Banks Island, Northwest Territories. Arctic 21(4):260-266.

Part of a metacarpal of *Ovibos* was found in 1963 on Banks Island, Northwest Territories, Canada, near 121°54'W, 73°23'N. The bone was indistinguishable from *Ovibos moschatus*. A Carbon-14 date in excess of 34,000 years was determined. The possible existence of a Wisconsin refugium on Banks Island is discussed. Evidence suggests that a refugium existed there isolated from Beringia. In addition to plant species, two small mammal species *Lemmus sibiricus* and *Lepus arcticus* and possibly muskoxen survived in the Banks Island refugium.

A.A.

532. MANGERUD, J., and S. GULLIKSEN. 1975. Apparent radiocarbon ages of recent marine shells from Norway, Spitsbergen, and Arctic Canada. Quaternary Research 5(2):263-273.

The mean apparent radiocarbon ages of marine shells, collected alive before the initiation of atomic bomb testing, and also before the main input of dead carbon derived from fossil fuels, are found to be 440 yr for the coast of Norway, 510 yr for Spitsbergen, and 750 yr for Ellesmere Island, Arctic Canada. The relationship between these apparent ages and the oceanic circulation pattern is discussed. Also possible variations of the apparent ages back in time are discussed.

A.A.

533. MANLEY, G. 1961. Late and postglacial climatic fluctuations and their relationship to those shown by the instrumental record of the past 300 years. Annals of the New York Academy of Sciences 95(1):162-172.

Compares evidence on the smaller climatic fluctuations of recent centuries with that on the larger changes connected with the ice age. Vast accumulation and extension of ice sheets that probably began in Greenland in the Miocene, is the most significant result of large-scale climatic change of the ice age period. Recent climatic ameliorations and diminution of the arctic sea ice, are associated with increased meridional transport of warmth into the Arctic Basin, mainly through the atmosphere, but partly by means of ocean surface water. Author concludes that significant climatic fluctuation in the past required "persistence of circulation patterns" over periods up to many decades long; North Atlantic climate has become rather unstable during the past three-four centuries, perhaps because of the changes in the arctic ice; the marked climatic "oscillation" near the northeast Atlantic in 1688-1739 shows no close relation to either vulcanicity or sunspots, suggesting an oceanographic factor as explanation of such short-period changes.

A.B.

534. MARSHALL, P., and M.C. BROWN. 1974. Ice in Coulthard Cave, Alberta. Canadian Journal of Earth Sciences 11(4):510-518.

Coulthard Cave is located in the Crowsnest Pass area of southwestern Alberta, at an elevation of 2650 m above mean sea level. The entrance of the cave faces north, and all but one of the passages in the cave end in massive ice blockages. Oriented ice samples were removed and studied by crystallographic techniques in a cold laboratory which revealed a layering (not evident to the eye) similar to that formed by the freezing of a horizontal water surface, i.e. a 'pond'. Although present-day temperatures in the cave never exceed 0°C, large scallop-like depressions in the ice suggest slow erosion by sublimation. An experiment indicated a sublimation rate of 3 mm/yr. Sublimation of the ice permits entrapped sediment to reach the ice surface. Continual downward lowering of the ice surface facilitates the movement by normal trajectory of sediment toward the scallop edges where it forms interstitial ridges. These ridges form on both vertical and overhanging ice surfaces. It is concluded that the ice probably did not form during the Pleistocene Period but rather after the late Hypsithermal warm period.

A.A.

535. MARTIN, P.S. 1958. Pleistocene ecology and biogeography of North America. In: Zoogeography, a Symposium. American Association for the Advancement of Science, Publication 51:375-420.

A study of climatic and environmental changes in the Pleistocene and their role, and man's role, in the extinction of mammals. The climatic-environmental changes are outlined in detail from the full glacial down to the present, with maps illustrating the changing vegetation from the icecaps through the tundra and taiga to the subtropical belt. Extinction is analyzed as to its intensity during the Pleistocene, groups affected and spared, factors causing extinction, including possible role of man. Present arctic regions are included in the study, with numerous references to Alaska.

A.B.

536. MATHEWES, R.W. 1973. A palynological study of postglacial vegetation changes in the University Research Forest, southwestern British Columbia. Canadian Journal of Botany 51(11):2085-2103.

The postglacial vegetation of the University of British Columbia Research Forest was investigated using percentage and absolute pollen analysis, macrofossil analysis, and radiocarbon dating. A marine silty clay deposit records the oldest (12 690 ± 190 years before present (B.P.)) assemblage of terrestrial plant remains so far recovered from the postglacial of south-coastal British Columbia. Lodgepole pine (*Pinus contorta*) dominated this early vegetation, although some *Abies, Picea, Alnus* and herbs were also present. Sediment cores from two lakes were also studied. The older is Marion Lake, where five pollen assemblage zone are recognized beginning with a previously undescribed assemblage of *Pinus contorta, Salix,* and *Shepherdia* in clay older than 12 350 ± 190 B.P. The pollen diagram from Surprise Lake (11 230 ± 230 B.P.) is divided into three pollen zones which show the same major trends of vegetation change as the Marion Lake diagram. The first report of postglacial vegetation history of cedar (*Thuja* and perhaps *Chamaecyparis*) in southwestern British Columbia is presented from pollen and macrofossil analyses.

At about 10 500 B.P. in both lakes, pollen of Douglas fir (*Pseudotsuga menziesii*) began a rapid increase, probably in response to climatic amelioration. The palynological evidence, supported by well-preserved bryophyte subfossils, suggests that humid coastal conditions have prevailed in the study area since about 10 500 B.P., with virtually no evidence for a classical Hypsithermal interval between 8500 B.P. and 3000 B.P.

A.A.

537. MATHEWES, R.W. 1978. Palynology and paleoenvironmental interpretation of sediments at the Point Grey sea-cliffs, southwestern British Columbia. American Quaternary Association, National Conference, Abstracts 5:222.

Pollen analyses were carried out on peat and organic silt samples dated about 25,000 ± 600 B.P. (GSC-109) from exposures along Wreck Beach. Samples were collected 7 to 8 m above beach level, at the contact between Quadra Sand and underlying silty beds which are referrable either to the Cowichan Head Formation or the Quadra Sand unit. All samples are dominated by non-arboreal pollen (82-96%), principally Cyperaceae, Gramineae, and Compositae. Sedge pollen ranges between 49% and 88%, suggesting local overrepresentation, which is confirmed by anthers, leaves, and achenes in the sediments. Present-day alluvial marshes and delta-front marshes of the Fraser River exhibit pollen assemblages similar to the Point Grey samples in their high sedge and grass pollen content and the presence of *Salix, Potentilla, Equisetum*, and cf. *Periconia*.

Arboreal pollen types found at Point Grey are *Pinus contorta, Picea*, and *Alnus*, with only sporadic occurrences of *Abies, Betula, Pinus albicaulis/monticola, Tsuga heterophylla, Tsuga mertensiana*, and Cupressaceae. Their relatively low abundance is due in part to high local presence of NAP, but may also suggest a predominantly upland origin for most taxa.

After comparison with reference material, *Polemonium* pollen are identified as belonging to the *Polemonium caeruleum* complex, suggesting a cooler climate at the time of deposition than at present. The presence of *Polygonum bistortoides/viviparum, Artemisia, Gentiana, Thalictrum, Botrychium*, Caryophyllaceae, and others also supports the interpretation of cooler climate, perhaps similar to present-day subalpine conditions. High pollen concentrations in the sediments (60,000-120,000 grains/ml) suggest that conditions were not severe enough to be termed alpine or arctic around 25,000 B.P.

A.A.

538. MATHEWES, R.W. 1979. A paleoecological analysis of Quadra Sand at Point Grey, British Columbia, based on indicator pollen. Canadian Journal of Earth Sciences 16(4):847-858.

Pollen and spore percentages and concentrations were determined from six peaty zones about 24500 radiocarbon years old at the Point Grey sea cliffs. All samples are dominated by nonarboreal pollen, especially Cyperaceae of local origin and Gramineae. Analysis of 'indicator pollen' suggests that two floristic elements were present, a local wetland component and a montane to subalpine element. This study supports the geological contention that the Quadra Sand was deposited in a braided river environment under a cooler macroclimate than exists at present. Pollen concentrations in the samples are within the range of some bog and lake sediments presently accumulating in the Fraser Lowland area of southwestern British Columbia, suggesting that climatic conditions were not of alpine severity around 24500 BP, although the indicator pollen assemblage suggests a climatic regime similar to present-day midmontane or subalpine conditions.

A.A.

539. MATHEWES, R.W, C.E. BORDEN, and G.E. ROUSE. 1972. New radiocarbon dates from the Yale area of the Lower Fraser River Canyon, British Columbia. Canadian Journal of Earth Sciences 9(8):1055-1057.

Three new radiocarbon dates from two lakes near Yale, B.C. established that ice-free conditions existed in parts of the Lower Fraser Canyon as early as 11 430 ± 150 B.P. A volcanic ash layer found in both lakes is considered to have come from the Mount Mazama eruption, based on a radiocarbon date from Squeah Lake. Mention is made of the problematic relationship of the three new dates to post-Vashon chronology in this area.

A.A.

540. MATHEWES, R.W., and J.J. CLAGUE. 1982. Stratigraphic relationships and paleoecology of a late-glacial peat bed from the Queen Charlotte Islands, British Columbia. Canadian Journal of Earth Sciences 19(6):1185-1195.

The stratigraphic relationships of late-glacial and Holocene sediments exposed in sea cliffs at Cape Ball on the Queen Charlotte Islands are summarized, based on section descriptions and 13 radiocarbon dates on wood, peat, and marine pelecypod shells. One peat bed dated at 12 400 ± 100 years BP (GSC-3112) to 10 200 ± 90 BP (GSC-3159) was investigated for pollen and plant macrofossils. This study extends the late Pleistocene vegetation history of the Queen Charlotte Islands by about 1550 years, and suggests that the record will date back to before 13 700 ± 100 BP (GSC-3222).

Four local pollen zones are described from the 70-cm-thick peat, herb-dominated zone (CB-1), characterized by up to 60% grass pollen, and including a unique assemblage with abundant Apiaceae, Cyperaceae, *Empetrum*/Ericaceae, *Polemonium, Plantago macrocarpa, Fritillaria*, and *Ranunculus*. A high diversity of other herbs, including subalpine/alpine species and two taxa presently absent from the Charlottes (*Armeria maritima* and *Polemonium caeruleum* type), suggests that this zone represents an open floodplain vegetation with no modern analogue. Zone CB-2 (63-45 cm) is dominated by *Pinus contorta* type pollen (65-70%) and moderate values for fern spores. Zone CB-3 (45-30 cm) shows a rapid rise of *Picea* pollen from 3 to 39%, followed by a drop to about 12%. Fern spores (20-50%) and *Alnus* (6%) also reach maximum levels in this zone. Abundant wood fragments and sand inclusions are compatible with an interpretation of a swampy floodplain forest during this interval. The uppermost zone (30-0 cm) exhibits high *Pinus contorta* (40-60%) and Cyperaceae (12-38%) values, along with a moderate abundance of grasses, ferns, and Apiaceae. Estuarine and marine sediments with pelecypod shells, deposited during a marine transgression, overlie the peat bed.

Implications for the controversy over the existence of late Pleistocene refugia in the Charlottes are briefly discussed.

A.A.

541. MATHEWES, R.W., and L.E. HEUSSER. 1981. A 12 000-year palynological record of temperature and precipitation trends in southwestern British Columbia. Canadian Journal of Botany 59(5):707-710.

Transfer functions for converting pollen frequencies to estimates of mean July temperature and mean annual precipitation were applied to fossil pollen data from a sediment core in Marion Lake. The paleotemperature curve shows low July temperatures near 14°C at the base of the core at about 12 000 before present (B.P.), rising rapidly between 10 400 B.P. and 10 000 B.P. to maximum values slightly above 16°C. Maximum temperatures cluster between 10 000 B.P. and approximately 7500 B.P., declining steadily thereafter until 6000 B.P. Little change is apparent from 6000 B.P. to the present. The reconstructed precipitation curve also shows a three-part zonation, with moderately high values between 12 000 and 10 400 B.P. dropping rapidly to minimum Holocene values between 10 000 and 7500 B.P. Precipitation rises to modern levels near the Mazama ash bed. The informal term "early Holocene xerothermic interval" is applied to the pre-Mazama interval of maximum temperatures and minimum precipitation.

The late-glacial age at the base of the core is confirmed by a new radiocarbon date of 11 920 ± 245 years B.P. (I-6857) on lodgepole pine needles screened from the basal clays.

A.A.

542. MATHEWES, R.W., and G.E. ROUSE. 1975. Palynology and paleoecology of postglacial sediments from the Lower Fraser River Canyon of British Columbia. Canadian Journal of Earth Sciences 12(5):745-756.

The postglacial history of vegetation in the Yale area of the lower Fraser River Canyon is described from sediments of two lakes using percentage pollen analysis supplemented with macrofossil evidence and radiocarbon dating. Deposition of postglacial sediments, ranging from basal clays to gyttjas, began about 11 500 y B.P. Three distinct pollen assemblage zones are distinguished, reflecting in part the main climatic conditions for the intervals. The oldest zone, with high percentages of pine (*Pinus*) and alder (*Alnus*) pollen, suggests cool and moist conditions following withdrawal of glacial ice. This is followed by marked increases in Douglas-fir (*Pseudotsuga*), grasses and other nonarboreal pollen, suggesting, in part, warmer and drier conditions. The third zone, ranging from about the Mt. Mazama ash at 6600 y B.P. to the present, is marked by high alder and Douglas-fir, and increasing cedar (*Thuja-Chamaecyparis* type), western hemlock (*Tsuga heterophylla*), fir (*Abies*) and birch; an assemblage indicating a return to wetter conditions. This sequence contrasts with previously described successions that recognized the classical Hypsithermal in adjacent areas. The sequence of inferred vegetational changes, although similar to those described for the Haney area to the west, suggest that the Yale area has been a biogeoclimatically transitional area for much of postglacial time.

A.A.

543. MATHEWS, W.H. 1951. Historic and prehistoric fluctuations of alpine glaciers in the Mount Garibaldi map-area, southwestern British Columbia. Journal of Geology 59(4): 357-380.

Historical, botanical, and geological studies in a part of the Coast Mountains of British Columbia show that all the existing glaciers of that area are retreating from climaxes attained in the early part of the eighteenth century and in the middle of the nineteenth century. A rapid rate of shrinkage, amounting to a loss in depth of as much as 12½ feet of ice annually, has prevailed however, only since the second and third decades of this century and has coincided approximately with a relatively warm period indicated by meteorological records. In three of four glaciers studied, the maximum advance of the last three centuries exceeded any other since the latter part of the Pleistocene epoch, and one of these three glaciers has been as extensive as it was in 1947 for only about four centuries since the deglaciation of its basin by the Cordilleran ice sheet in late Wisconsin time. For a fourth glacier, however, the advances of the past few centuries failed by far to reach the limits of a much earlier, probably late Pleistocene, advance. Reduction in its potential accumulation area as a result of unusually rapid lowering of its cirque head wall by erosion may account for the anomalous behavior of this glacier. Many low-level cirques, formed by early or pre-Wisconsin alpine glaciation, have not been reoccupied by local bodies of ice during or since the disappearance of the Cordilleran ice sheet.

A.A.

544. MATHEWS, W.H. 1978. The geology of the ice-free corridor; discussion; northeastern British Columbia and adjacent Alberta. American Quaternary Association, National Conference. Abstracts 5:16-18.

The last ice sheets to have covered northeastern British Columbia and adjacent Alberta have left a clear record of their presence and movement in the existing land forms and surficial deposits: grooves and drumlins, meltwater channels, erratics and drift sheets, and traces of former ice-dammed lakes. Air photo and map interpretation supplemented by limited data on surficial material have been used to reconstruct the history of the ice retreat.

Three glacier systems were involved: the Laurentide ice sheet originating over the Canadian Shield, the Cordilleran ice sheet originating in the interior of British Columbia, and a system of valley glaciers from the northern Rocky Mountains (between latitudes 57° and 59° north).

At the climax of the last glaciation all the area was ice-covered (Fig. 1) except for the high summits and ridges of the northern Rocky Mountains. The earliest exposure of land east of the mountain front between latitudes 56° and 60° north was closed to the Alaska Highway where relatively high-level lakes and meltwater channels were developed. A series of large lakes, dammed by Laurentide ice, then developed in the Peace River valley, with water levels falling as retreating ice exposed lower outlets. The extent of these lakes has been interpreted from the distribution of shorelines, bottom deposits, tributary and outlet channels. The disposition of Laurentide ice farther north is inferred from ice-flow patterns, meltwater channels, and glaciological considerations. The contemporaneous positions of Cordilleran and Rocky Mountain ice fronts (Fig. 2) can in some stages be inferred from the elevations of lakes, or of spillways controlled by Laurentide ice. Laurentide ice withdrew more rapidly from the area than did Cordilleran ice, and a very late local ice advance from the northern Rocky Mountains is indicated.

Most of the retreatal stages discussed date back to the period from about 13,500 to 10,000 years BP.

A.A.

545. MATHEWS, W.H. 1979. Late Quaternary environmental history affecting human habitation of the Pacific Northwest. Canadian Journal of Archaeology 3:145-156.

This paper reviews the record of late Quaternary environmental conditions and suggests how these could have affected habitation by early man in the Pacific Northwest. Emphasis is given to conditions since about 30,000 B.P. so as to include the possibility of human habitation before the last climax of glaciation, 15,000 years ago. The environments in the coastal area of British Columbia and Washington have been stressed as this is where most data have so far been collected, but in recognition of speculations concerning passage of early man through the interior of British Columbia some thoughts have been offered for this area as well. Whether man did, in fact appear on the scene to face these conditions during or before the last glaciation is as yet unresolved, but the problems he might have faced had he done so still merit consideration.

A.A.

546. MATTHEWS, B. 1967. Late Quaternary marine fossils from Frobisher Bay (Baffin Island, N.W.T., Canada). Palaeogeography, Palaeoclimatology, Palaeoecology 3(2):243-263.

Eighteen species of fossil marine pelecypod and eighteen species of Foraminifera collected from raised beach deposits (with strandlines at 27 ft., 48 ft., and 77 ft. above sea-level) at Frobisher Bay, yield possible evidence of postglacial changes in the marine environment.

A few of the little-known species of pelecypod are described. Six of the species are recorded for the first time in raised marine deposits of arctic Canada: two are pan-arctic species (i.e., *Axinopsida orbiculata* and *Yoldia fraterna*) and three species (i.e., *Volsella demissa, Nucula delphinodonta, Lyonsia hyalina*) do not occur in Canadian arctic waters at the present time and suggest more favourable environmental conditions during the Atlantic climatic phase. The present distribution of the other species, *Yoldia sapotilla*, is still uncertain.

The presence in sediments at 21 ft. above sea level of temperate Foraminifera *Globulina inaequalis* and the pelagic Foraminifera *Orbulina universa* may also point to warmer conditions about 6,000-6,500 years ago.

Radiocarbon datings of 6,140 ± 170 and 6,440 ± 160 years B.P. were determined on shells from 48 ft. and 11 ft. above sea-level respectively. The latter date indicates the upper part of Frobisher Bay was deglaciated at least 6,500 years ago, while the former date suggests an average land emergence of about 1 ft./century in the last 6,000 years.

A.S.

547. MATTHEWS, B. 1967. Late Quaternary land emergence in northern Ungava, Quebec. Arctic 20:176-202.

Twenty-one C^{14} dates of material from Late Quaternary marine terraces are used to construct an isostatic uplift curve. The phase of rapid uplift averaged about 26 ft. per 100 years, while for the past 5,200 years uplift was just under 1 ft. per 100 years. Updoming resulted in an upward (southerly) tilt of the "Glacier Beach" (460-ft. strandline) and "Upper Tunit Beach" (100-ft. strandline) at about 5.6 ft. per mile and 3.6 ft. per mile respectively. The C^{14} dates indicate that the general deglaciation of northern Ungava occurred about 7,000 to 8,000 years ago. Twelve well-formed marine terraces have been identified at the heads of the major fjords. The fauna of the "Upper and Lower *Aporrhais* Beaches" (40 ft. and 55 ft. strandlines) suggests that optimal marine conditions occurred about 3,900 to 5,230 radiocarbon years ago during a possible marine transgression. Hydroclimatic conditions during the formation of *Aporrhais* deposits in Sugluk Inlet (62°10'N) corresponded to those at 58°15'N.

A.A.

548. MATTHEWS, B. 1975. Archaeological sites in the Labrador-Ungava Peninsula: cultural origin and climatic significance. Arctic 28(4):245-262.

Ruins of structures in Arctic Quebec and Labrador were investigated, all apparently less than 1,500 years old and abandoned by their Eskimo inhabitants more than 150 years ago. ... From radiocarbon dating of fossilized animal bones, it is concluded that some of the structures were occupied during a mild period 600-700 years ago. Climate and vegetation of that period were reconstructed from pollen analysis and fossil remains.

pA.A.

549. MATTHEWS, J.V., Jr. 1975. Use of Late Cenozoic beetle fossils for dating and correlation. Quaternary Non-marine Paleoecology Conference, University of Waterloo, Waterloo. Program and Abstracts.

The documented slow rate of evolution among Coleoptera (beetles) during the Quaternary seems to preclude the use of their fossils for dating and correlation. This paper provides several examples to show that this supposition may not be entirely true.

Fossils of extinct species referred to *Helophorus (Cyphelophorus)* occur in an assemblage from the Beaufort Formation on Meighen Island (Queen Elizabeth Islands, N.W.T.) and in the 5.7 million year old Lava Camp assemblage from western Alaska. The Lava Camp *Cyphelophorus* species seems to be the most primitive known member of a lineage leading through the Meighen Island species to the extant *H. (Cyphelophorus) tuberculatus* Gyll. If so, Beaufort sediments on Meighen Island are probably younger than 5.7 million years, a fact not indicated by other paleontological evidence.

Such stages of evolution criteria may be applicable in special cases to Quaternary sediments. For example the established sequence portraying reduction of flight wings in *Tachinus apterus* Makl. during the Pleistocene may be useful for dating *T. apterus* fossil flight wings of unknown age. Such fossils occur at several Alaskan sites.

Late Tertiary assemblages from Alaska and Canada are known to contain fossils of several strictly Palaearctic taxa. Fossils of these from other sites will have increasing chronologic significance as the time of North American extinction of these Old World taxa is discovered.

Finally the overall taxonomic composition and diversity of fossil insect assemblages often have age implications. This is especially true in areas such as parts of the Arctic Archipelago where entire insect orders are missing as a result of the severe climate. In such cases very small assemblages of fossils may have chronologic significance.

A.A.

550. **MATTHEWS, J.V., Jr. 1975. Insects and plant macrofossils from two Quaternary exposures in the Old Crow - Porcupine region, Yukon Territory, Canada. Arctic and Alpine Research 7(3):249-259.**

Insect fossils and plant macrofossils have been recovered at two exposures in the Old Crow-Porcupine region, (northern Yukon Territory). One assemblage of fossils, from an exposure on the Porcupine River in the Bluefish Basin, is probably about 32,400 years old, while the other, from an exposure in the Old Crow Basin, is older than 44,000 years.

Both assemblages seem to have been deposited when the sites from which they come were within a region of forest-tundra. The Porcupine River assemblage indicates that tree line along the middle Porcupine drainage during mid-Wisconsin time was significantly lower than at present. At that time more northern areas such as the Old Crow Basin would have been totally treeless in contrast with the forest-tundra vegetation there today.

The Old Crow assemblage probably represents climatic conditions as warm as at present. It includes fossils of one insect species and two plant species that do not occur today in the Old Crow Basin. The insect, a beetle (*Micralymma brevilingue* Schiødt) is now found farther north in a special type of tundra habitat. One of the plants, *Alnus incana*, may be absent today simply because of paucity of suitable habitat. The other, *Najas flexilis*, has a contemporary northern limit far to the south of the Yukon Territory. Because *Najas* does not grow in the Yukon Territory today, it is possible that its fossils imply warmer climate. However, such a conclusion is tempered by the further possibility that *Najas* is absent today not because of present climatic conditions but because of the severity of late Wisconsin climate in eastern Beringia (the Alaska-Yukon unglaciated refugium).

A.A.

551. **MATTHEWS, J.V., Jr. 1975. Incongruence of macrofossil and pollen evidence: a case from the late Pleistocene of the northern Yukon coast. Geological Survey of Canada Paper 75-1B:139-146.**

This paper deals with a small assemblage of plant and animal macrofossils and pollen from a coastal Yukon site near the Alaska border.

The fossils indicate a tundra environment. Dwarf birches were growing at the site, yet this fact is not clearly indicated by the pollen evidence. A similar case of incongruent pollen and macrofossil evidence from a site near Inuvik, N.W.T. is cited to illustrate a potential danger of relying on pollen evidence alone to plot the dispersal history of plants.

[The macrofossils are dated at about 11,000 years BP. According to the author, extralimital plant individuals someday may serve as sensitive indicators of short term climatic change.]

pA.I.$^+$

552. MATTHEWS, J.V., Jr. 1976. Arctic-steppe; an extinct biome. American Quaternary Association, National Conference, Abstracts 4:73-79.

Paleoecological studies over the past 15 years in unglaciated Alaska and the Yukon Territory provide strong evidence that during the late Pleistocene these regions, when joined with central and eastern Asia by the Bering Land Bridge, constituted the eastern end of a huge grassland biome, unequalled today in size or character. It has been called periglacial-steppe, tundra-steppe and steppe-tundra; however, the term arctic steppe seems more appropriate since it reflects both the regional extent of the environment as well as its dissimilarity to contemporary tundra.

The tenure of arctic-steppe coincides with exposure of the Bering Land Bridge and adjacent areas of the continental shelf. Accordingly, it may be assumed that the arctic-steppe climate of Siberia and Alaska-Yukon was more continental than at present. However, differences of physiography and variation in width of the arctic continental shelf dictate that all areas occupied by the arctic-steppe biome were not equally continental.

Arctic-steppe climate was "arctic" in terms of mean annual temperature, but because of its continentality summers may have been relatively warm and dry. Such conditions are probably responsible for the distinctly non-tundra substrate conditions that are implied by fossils of certain plants, mammals, and insects in late Pleistocene Alaska-Yukon and Siberian fossil assemblages. Indirect phytogeographical data also suggest presence of certain steppe plant species that cannot grow in western Alaska and far eastern Siberia today. While favouring some plants arctic-steppe summer climate was undoubtedly inimical to others. Thus it is possible that the rarity of spruce and several common tundra shrubs in arctic-steppe assemblages is due to aridity, not cold temperatures.

In Alaska-Yukon the decline of the arctic-steppe environment is signaled by an abrupt increase in abundance of shrub birch 12,000 to 14,000 years ago. Steppe conditions continued to persist in some regions, possibly due to the feedback effect of the large mammal community, some members of which apparently survived until 10,000 years ago. At that time the land bridge was submerged and large areas of tundra and taiga were once again forming in northern areas. By 8500 years ago the arctic-steppe biome had disappeared. A similar contraction of steppe lands must have occurred at the end of the Illinoian glaciation, but did not result in the extinction of so many of the megafauna species. Man was a part of the Wisconsinan arctic-steppe biome, and its demise may be a function of his contribution to the extinction of the large ungulates as their range (and gene pools) became constricted in the face of expanding forests and tundra.

pA.A.

553. MAXWELL, J.B. 1981. Climatic regions of the Canadian Arctic Islands. Arctic 34(3): 225-240.

A comprehensive assessment of the climate of the Canadian Arctic Islands and adjacent waters led to identification of five climatic regions. Temperature trends, based on modern meteorological records, are given. The northwestern region indicates a gradual temperature decrease from the early 1950s into the 1970s followed by a levelling out or even a slight increase. The south-central region is characterized by a gradual temperature decrease from the late 1940s to the early 1960s followed by a slight increase. No conclusive trends are evident in the western region. In the eastern part of the eastern region, temperatures rise to a peak in the early to mid-1950s and decline thereafter. Farther north, temperature declined since the mid-1950s. In the northern region, Alert and Eureka show a marked temperature decrease from the early 1950s through the 1970s. Since at least the early 1960s there has been measurable climatic cooling in the northern and eastern Arctic, but this cooling is not greatly reflected in the central and western Arctic south of Parry Channel.

C.R.H.

554. MAYBANK, J. 1981. Climate Change - the potential impact for the Prairie Provinces. In: Climate Change Seminar Proceedings. Regina, March 17-19. Canadian Climate Centre, Downsview. pp. 122-128.

"The Prairie Provinces are a particularly good area to seek out the effects of possible climate change scenarios as they lie near the low temperature boundary of preferred human inhabitation, viz. the 2°C annual isotherm. The prairie climate displays marked variability. Agriculture is especially sensitive and I shall tend to concentrate on the effects of various cimate changes on it. However, other activities are not immune."

As one example, a simple all-season warming trend extended through 20 years or so will be beneficial in terms of energy use reduction. However freeze-up delay would be detrimental to transport activities in the north. The author considers other climate changes in a similar fashion.

A.B.S.

555. McALLISTER, D.E., and C.R. HARINGTON. 1969. Pleistocene grayling, *Thymallus*, from Yukon, Canada. Canadian Journal of Earth Sciences 6(5):1185-1190.

Eleven cycloid scales from Pleistocene deposits in the Old Crow area, Yukon Territory, radiocarbon dated by shells from the same horizon at 32,400 ± 770 year BP, appear to be inseparable from those of recent Arctic grayling, *Thymallus arcticus* (Pallas, 1776). They provide the first fossil record of the genus *Thymallus* and the subfamily Thymallinae for North America, and confirm previous suggestions that *Thymallus arcticus* survived the Wisconsin glaciation in the Beringian refugium. ... Associated faunal and floral evidence suggests that the graylings lived in a cool, shallow lake with wet meadow habitat and coniferous trees nearby.

pA.C.

556. McANDREWS, J.H. 1972. Pollen analyses of the sediments of Lake Ontario. 24th International Geological Congress, Montreal, Section 8:223-227.

Analyses were made on 91 surface sediment samples and values were derived of both percentages and concentrations (grains per gram dry sediment) of 61 taxa. Concentration was highest, over 80,000 in the deep-water clays, but was less than 40,000 in shallow, near-shore silts and sands. Pollen of ragweed and tree pollen, especially pine and oak, dominate the relatively uniform assemblage, however, the significant percentage variations reflect nearness to upland source regions, river discharges and recycling of sediment.

Two deep-water (over 180 m) cores at stations 80 km apart penetrated 5 to 7 m of postglacial sediment and 9 to 11 m of late-glacial sediment. Eight pollen assemblage zones are present and correlate with radiocarbon- and varve-dated pollen assemblages from sediment of nearby small lakes. The pollen concentration of the seven postglacial zones is 35 times greater than the Late-glacial spruce zone reflecting both greater pollen influx and lesser rate of matrix accumulation. The ragweed zone begins at a depth 15 to 20 cm from the surface and represents forest clearance around the Lake beginning in the early 19th century.

A.A.

557. McANDREWS, J.H. 1973. Pollen analysis of the sediments of the Great Lakes of North America. In: Holocene Palynology and Marine Palynology. Edited by: N.A. Khotinsky and E.V. Koreneva. Proceedings of the 3rd International Palynological Conference, Moscow. pp. 76-80.

The Great Lakes began to form about 14,500 years ago with the retreat of glacial ice. Lake levels were primarily controlled by changing outlet elevations related to ice dams and isostatic rebound. Sediments of the Great Lakes contain pollen assemblages similar enough to the traditionally studied assemblages of small lakes to make stratigraphic correlations. Differences in contemporaneous assemblages from Great Lakes and small lakes are related to vegetation of the source region, mode of transport and recycling of older sediments. Pollen diagrams contribute to the history of the Great Lakes by providing information on the chronology and environment of sedimentation.

A.S.

558. McANDREWS, J.H. 1976. Holocene pollen analysis from northern Quebec. American Quaternary Association, National Conference, Abstracts 4:111.

A lake in the forest-tundra at 56°N, 64°W was cored to a depth of 270 cm. Four C-14 dates range from 500 years at the surface to 4,100 years near the bottom. The percentage pollen diagram is generally similar to nearby published diagrams in indicating a succession from sedge-willow tundra to birch-alder tundra followed by a spruce-dominated forest-tundra for the last 3,000 years. However, the pollen influx indicates that the maximum abundance of spruce trees was 3,000 years ago and that since then a "palynologically silent" lichen-heath tundra has become widespread. This reduction of trees and spread of tundra is somewhat similar to published reports from western Canada.

A.A.

559. McANDREWS, J.H. 1981. Late Quaternary climate of Ontario: temperature trends from the fossil pollen record. In: Quaternary Paleoclimate. Edited by: W.C. Mahaney. Geo Abstracts, Norwich. pp. 319-333.

In eastern Ontario, zonal vegetation boundaries parallel isotherms of mean annual temperatures. Because modern pollen rain reflects zonal vegetation one can trace zonal vegetation and temperature trends with critical pollen diagrams from the time of deglaciation (14,000 BP).

Immediately after deglaciation temperature was -2°C or lower. It rose to the modern value of +9°C by 8000 years ago in southern Ontario. In northern Ontario a modern temperature of +1°C was reached about 6500 years ago--this was followed during the next millenium by a Hypsithermal of +2°C to +3°C. However, there is no indication of a mid-Holocene Hypsithermal in southern Ontario.

A.A.

560. McANDREWS, J.H., M. BOYKO, R. BRYNE, and B. FINLAYSON. 1974. Investigations at Crawford Lake. Friends of the Pleistocene, 37th Annual Reunion, Toronto. pp. 1-10.

... two distinct episodes of agriculture can be recognized in the Crawford Lake sediments of the last millenium. An important application of varve chronology to vegetation reconstruction is that dates for regionally recognized pollen events may be correlated with neighbouring lakes having massive sediments. Rates of sedimentation and pollen influx may then be calculated.

pA.C.

561. McANDREWS, J.H., M. SAARNISTO, and R.J. ADAMS. 1975. Pollen and plant macrofossils in four Lake Nipissing deposits near Georgian Bay, Ontario. Quaternary Non-marine Paleoecology Conference, University of Waterloo, Waterloo. Program and Abstracts.

Lake Nipissing beaches surround Georgian Bay at elevations of up to 35 meters above modern water level. Holocene uplift and erosion at the St. Clair River outlet account for the elevation. Gravel mining, ditching and stream dissection produced four sections containing organic horizons that range in radiocarbon age from 6800 to 5530 years BP. These dates and their elevations agree with previously published estimates of the rate of uplift.

Pine dominates the pollen assemblages except in the southernmost section where hemlock is co-dominant. Pollen, leaves and seeds of tamarack, willow, sweet gale, water-willow, sedge, water milfoil, naiad, water lily and other aquatic plants indicate that shrubby bogs, marshes and shallow ponds occupied local depressions. Subsequent water level rises to the Lake Nipissing maximum about 5500 years ago caused these organic accumulations to be buried beneath sand and gravel.

A.A.

562. McANDREWS, J.H., et G. SAMSON. 1977. Analyse pollinique et implications archéologiques et géomorphologiques, lac de la Hutte Sauvage (Mushuau Nipi), Nouveau-Québec. Géographie physique et Quaternaire 31(1-2):177-183.

Two pollen cores were collected in the northern section of Indian House Lake and pollen analysis revealed a 4-phase vegetative history of 4,100 years: 1) herb tundra (4,700-4,100 BP); 2) shrub tundra (4,100-3,700 BP); 3) rich forest-tundra (3,700-2,500 BP); 4) present forest-tundra (2,500-0 BP). Pollen influx analysis indicates that the shrub-tundra was rather rich. Trees began to colonize the area about 4,000 years BP and reached a climax ca. 3,000 BP. From 2,700 BP, the vegetation becomes impoverished and at about 2,500 BP a climatic change caused the lowering of the tree limit and the thinning of the taiga patches. Pollen data allows the reconstruction of the vegetative environment in which the prehistoric populations of the Mushuau Nipi evolved. Also, we suggest a direct effect of the major vegetative and climatic changes on the ecosystem. Finally, the ^{14}C dating of the pollen cores (4,100 BP and 3,700 BP) introduces certain problems concerning the post-glacial and pro-glacial lake stages at Indian House Lake. The lower terrace system (0-35 m above lake level) on which all the archaeological sites were found did not begin to form earlier than about 4,000 BP.

A.A.

563. McGHEE, R. 1970. Speculations on climatic change and Thule culture development. Folk 11/12:173-184.

Environmental changes, and especially climatic changes, are the primary variables traditionally cited by Arctic prehistorians as explanation for cultural variations. The necessary relationship between climatic change and cultural modification is obvious in a climatically marginal area such as the Arctic, but until very recently our knowledge of climatic conditions over the past millenium could support only simplistic statements suggesting a loose relationship between gross cultural and climatic events. Recently however, several lines of evidence (shifts in the northern limit of the boreal forest, glacial advances on the eastern Arctic islands, palynological and peat accumulation studies, Scandinavian historical records) have converged to allow the construction of a basic sequence of climatic episodes which have occurred in the Canadian Arctic over the past 1000 years.

From a general knowledge of human ecology in Arctic regions, we may suggest that there were two non-climatic environmental variables of paramount importance to aboriginal cultural adaptions over the past 1000 years: (1) the annual and seasonal distribution of various types of sea ice, and (2) the annual and seasonal availability of various species of food animals, especially sea mammals. Both of these variables are strongly influenced by changes in weather patterns from one year to the next. A series of hard winters or long summers could produce significant changes in the 'expected distribution' of sea ice or sea mammals, and aboriginal cultural patterns must have been closely adjusted to these 'expected distribution' parameters. By postulating the effect of known climatic changes on these two variables, we can construct a speculative model of culturally-significant environmental changes in the North American Arctic over the past millenium. Hypotheses regarding the nature of Thule culture development arise from an attempt to fit archaeological evidence to this speculative model of environmental change.

[A discussion of climatic episodes over the past 1000 years details the above model].

Excerpts⁺

564. McGHEE, R. 1972. Climatic change and the development of Canadian Arctic cultural traditions: In: Climatic Change in Arctic Areas During the Last Ten Thousand Years. Edited by: S. Vasari, H.H. Hyvärinen and S. Hicks. Acta Universitatis Ouluensis Series A, Scientiae Rerum Naturalium 3, Geologica 1:39-60.

The archaeological evidence presently available from Arctic Canada allows us to make only tentative and generalized statements relating to the human responses to past climatic changes. The reponses which suggest adaptation to ameliorated climatic conditions, probably as expressed in decreased extent of sea ice and greater availability of food animals, are listed in Figure 2. In comparing these cultural indicators with the Greenland ice core measurements (Dansgaard *et al.* 1969), and the position of the forest limit in Keewatin (Nichols 1968), it is apparent that the correlation of culturally indicated warm periods with warm periods as indicated by the other lines of evidence is at best general.

A closer correlation appears to exist between the ends of the culturally indicated warm periods and episodes of rapid or extreme cooling as suggested by the other lines of evidence. This is the sort of correlation which might be expected in dealing with human adaptations to Arctic conditions. It would seem likely that negative responses to deteriorating conditions, e.g. population reduction through starvation or abandonment of an area, would have occurred much more rapidly than positive responses to ameliorating conditions involving several decades or even centuries of technological adjustment and population increase.

A.C.

565. McGHEE, R. 1979. Archaeological evidence for climatic change during the past 5000 years. International Conference on Climate and History, University of East Anglia, Norwich, July 8-14. Review Papers, pp. 109-127.

"Recent archaeological work on the northern islands of Arctic Canada is briefly described. Prehistorical occupation of these islands appears to have been conditioned by sea ice distribution, which can be correlated with climatic variables. The area supported human occupation during the periods of approximately 4000-3500 BP, 3000-2500 BP, and 1500-300 BP." The nature and extent of the summer sea ice "directly conditions the density and distribution of sea mammal populations, the primary food resource of most Arctic island peoples. Indirectly, the amount of open water influences the amount of precipitation falling on the High Arctic, and is a factor in the amount of food available for the herbivores (muskoxen and caribou) which are the other major food resource of the area."

A review of human occupation of the Barren Grounds is presented. The alternating occurrences of Paleoeskimo and Indian populations suggest climatic influences; "tundra was more extensive between 500 and 1000 BC."

Excerpts⁺

566. McLELLAN, H.J. 1955. Changes in bottom temperatures on the Scotian Shelf. Journal of the Fisheries Research Board of Canada 12(3):375-386.

A comparison of recent bottom temperatures on the Scotian Shelf with those observed in the period 1934 to 1939 shows that, in general, these temperatures have been higher by from one to three Centigrade degrees in the more recent period. The change has been due to the variation in the intermediate layer which was both colder and of greater thickness during the early period.

A.A.

567. McMANUS, D.A. 1970. Criteria of climatic change in the inorganic components of marine sediments. Quaternary Research 1(1):72-102.

The most commonly used criteria in marine sediments for detecting climatic changes are the remains of organisms and the position of the shorelines, for these two types of criteria can have a relatively quick response to climatic change. The inorganic components of marine sediments, however, also provide useful criteria. On the inner continental shelf where the best correlation should be found between modern terrigenous marine sediments and modern climates, sediment texture is the main criterion. Where land ice reaches the sea, gravel may be deposited, but much of the inner shelf in polar climates receives abundant mud, containing a small amount of clay minerals. From tropical humid climates abundant mud is delivered composed mainly of clay minerals, but knowledge of their composition is required, because the largest rivers do not have a dominance of tropical sediment products. In arid climates and midlatitude moderate rainfall climates, inner shelf sand is indicative, although it also possibly reflects the common entrapment of mud in estuaries and the presence of the middle latitude cyclone belt in which storms remove the fine material present on the inner shelf. Climate also controls extensive carbonate deposits. In deep-sea sediments composition contains more important criteria than texture. Some criteria appear to be reliable for various aspects of modern climates and therefore should be useful in detecting climatic changes. These criteria include the size, surface texture, and mineralogical and chemical composition of eolian transported material downwind of arid lands; global dust in latitudinal bands of atmospheric circulation; volcanic ash downwind of geologically instantaneous events; surface texture of quartz grains and the abundance of terrigenous material in pelagic sediments as indication of glaciation; chlorite from a polar climate; kaolinite from a tropical climate, and inorganically precipitated calcium carbonate in enclosed seas. Less definitive criteria are possibly the rate of turbidity current activity, iron-rich layers in the sediment, sedimentation from the nepheloid zone, construction of features by bottom currents, organic matter content, and sedimentation rate. Speculations include the intensity of benthic faunal reworking of sediment. Using these criteria it is possible to identify the sediment products of the extreme climates: polar, tropical rainy, and dry (desert), and thereby to infer the existence of these climates. The modern climates apparently are not so easily detected. The criteria also indicate the nature of the water, wind, and ice processes delivering the sediment products to the sea. Extreme values in the frequency or magnitude of the climate-associated processes have great significance in the supplying of terrigenous material, and changes in these extreme values could produce salient changes in the sedimentary sequence. The criteria of climatic change might well be considered criteria of change in extreme values of the processes.

A.A.

568. McROBERTS, J.H.E. 1968. Post-glacial history of Northumberland Strait based on benthic Foraminifera. Maritime Sediments 4(3):88-95.

The post-glacial history of Northumberland Strait may be postulated as follows: immediately after the deglaciation of the area, sea level was lower by approximately 71 metres (300 feet). At this time the Strait would be completely exposed to subaerial influences. Drainage of the area was most likely to the north through the Cape Breton trough to the Laurentian Channel. Inundation of the area by marine waters about 11,800 years B.P. flooded the Strait and opened the Isthmus of Chignecto. As conditions became warmer, *Crassostrea* *virginica* and *Ammonia beccarii* migrated into the region. Isostatic rebound in the area resulted in the closure of the Isthmus of Chignecto at 6400 ± B.P. (Bartlett, personal communication) and exposed the regions of core 3 and 11 to fresh water influence. At this time, water may have continued to drain through the Cape Breton trough. After 3000 ± B.P. marine waters again invaded the Strait. A reversal, in conjunction with a fresh water influx around 1700 ± B.P. resulted in a decline in the foraminiferal populations. This was followed by a brief period of more favourable conditions. The appearance of the depauperate fauna marked the onset of present Northumberland Strait conditions.

A.C.

569. MERCER, J.H. 1956. Geomorphology and glacial history of southernmost Baffin Island. Geological Society of America Bulletin 67:553-570.

The southernmost peninsula of Baffin Island is a tilted peneplane, with an escarpment along Frobisher Bay. During most of the Wisconsin age, precipitation in the area must have been low, and there is evidence that the higher parts of the escarpment remained above the ice. Cirques with submerged floors show that during a considerable part of the glacial ages sea level was lower than today. Strand lines up to 1425 feet A.T. indicate very great depression of the land in the late Wisconsin, possibly connected with an increase of ice in the Hudson Strait area as precipitation increased after the disappearance of the topographic barrier of the main Laurentide Ice Sheet. When the sea level was between 210 and 180 feet the overflow from an ice-dammed lake cut two great gorges and formed a large bay-head delta. The dam may have been the northern margin of an ice sheet centered in the Quebec-Labrador Peninsula. There is evidence of a warmer period in the recent past, and the present small icecaps are probably the rejuvenated relics of a larger icecap.

A.A.

570. MERCER, J.H. 1970. A former ice sheet in the Arctic Ocean? Palaeogeography, Palaeoclimatology, Palaeoecology 8(1):19-27.

Similarities of setting between the Arctic Ocean today and the former sea now occupied by the West Antarctic ice sheet and its associated ice shelves suggest that, under prolonged full-Glacial conditions, a cold ice cover of West Antarctic type could have developed in the Arctic Ocean, consisting of a complex of iceshelves and ice grounded far below sea level. During the Last Glacial the ice cover probably consisted of ice shelves only except for a grounded ice sheet in the epicontinental Barents Sea, but during an earlier Glacial, an ice sheet centered in the American sector of the Arctic Ocean may have extended onto the adjacent land, carrying shelly drift far above the marine limit in the Canadian Arctic islands, and inundating northwest Alaska.

A.S.

571. MEUNIER, G. 1981. The effects of climatic variation on the management of recreational facilities and resources in Quebec. In: Climate Change Seminar Proceedings. Regina, March 17-19. Canadian Climate Centre, Downsview. pp. 72-78.

"Climatic variation affects participation in outdoor recreational activities." The author considers two examples to illustrate the relationship between climatic variation and the management of an outdoor recreational resource: deer hunting and alpine skiing. The conclusion is that research on climate variation is essential.

A.B.S.

572. MILLER, A.A.L., P.J. MUDIE, and D.B. SCOTT. 1982. Holocene history of Bedford Basin, Nova Scotia: foraminifera, dinoflagellate, and pollen records. Canadian Journal of Earth Sciences 19(12):2342-2367.

Three piston cores from Bedford Basin, a silled coastal inlet, provide the basis for a micropaleontological study of postglacial to recent sediments. Five faunal units (four foraminiferal, one arcellacean) are found in core 79-11: a surface assemblage, followed by deep estuarine, marginal marine, transition, and freshwater (arcellacean) assemblages. The other cores contain only expanded marine sequences. The top of the transition zone in core 79-11 has a C-14 age of 5830 ± 230 years BP, indicating a rise in sea level of at least 20 m (the sill depth) during the Holocene.

Four dinoflagellate assemblage zones are found in core 79-11. The first (*O. centrocarpum* - *B. tepikiense*) is typical of a silled basin with marine water of near-normal salinity; the second (*P. conicoides* - Cyst C) indicates a temperate marine environment with strong fluvial influence (marginal marine); the third (*P. limbatum*) is dominated by freshwater cysts, and the fourth (Dinocyst sp. A) is dominated by subarctic brackish water cysts.

Four pollen assemblage zones are found in core 79-11. Zones C1-C3 indicate mixed boreal-deciduous forest vegetation. Zone B indicates early Holocene park-woodland vegetation, the base of which has a C-14 age of 7705 ± 550 BP. The palynozones in the marine sediment core are correlatable with C-14 dated stratigraphies from Nova Scotian lakes.

Foraminifera and dinoflagellate assemblages in core 79-11 reflect the response of the microfauna and microflora to changes in water depth, salinity, and temperature, which have accompanied changes in sea level and climate during the past 8000 years. Major changes in the marine biota during the recent period of urban development may be due to increased sediment influx and effluent discharge. The effects of anthropogenic changes are small, however, compared to those accompanying the Holocene marine transgression.

A.A.

573. MILLER, B.B. 1975. Nonmarine molluscs in Quaternary paleoecology. Quaternary Nonmarine Paleoecology Conference, University of Waterloo, Waterloo. Program and Abstracts.

The precision of reconstruction of Quaternary environments using nonmarine molluscs is related to the degree of certainty with which fossil material can be referred to living species. Knowledge of a demonstrated, implied or inferred relationship between living species and the environment, in which the effects of the interaction are expressed as limitation of geographic range, phenotypic variation in shell morphology or shell chemistry, forms the basis for environmental interpretations. Many such interactions have been described. Examples of some of these include: (1) distributional patterns related to temperature, available moisture, and soil composition (Drake 1973; Taylor, 1960; Oughton, 1948); (2) relationship of shell obesity and shell size to differences in the availability of food between lentic and lotic habitats (Ortmann, 1920; Berry, 1943), the size of the aquatic habitat (Van der schalie, 1938), and topographic elevation (Archer, 1948). The development of spinosity has been attributed to increased salinity (Leonard and Franzen, 1944). Variation in the development of apertural lamellae and smoothness of the shell have been correlated with change in elevation (Vagvolgyi, 1968). Variation in isotopic and trace element composition of shell material has been related to conditions in the local habitat (Weber and La Rocque, 1964; Nelson, 1967).

Limitations in the use of nonmarine molluscs are imposed by the uncertainties involved in the identification of certain species from shell material, inadequacy of distributional and ecological data for many living species, and the very real possibility that some physiological changes have developed in some species even though there may be no recognizable difference in shell morphology.

A.A.

574. MILLER, G.H. 1973. Late Quaternary glacial and climatic history of northern Cumberland Peninsula, Baffin Island, N.W.T., Canada. Quaternary Research 3(4):561-583.

Radiocarbon dates on molluscs in marine facies associated with glacial deposits in northern Cumberland Peninsula indicate both main fiord (Laurentide) ice and local glaciers remained at their late Wisconsin maxima until ca. 8000 BP. Essentially continuous deglaciation followed; local corrie glaciers melted out by 7100 BP and by 5500 BP fiord glaciers had receded behind the present margin of the Penny Ice Cap. The Hypsithermal warm interval probably lasted from ca. 8000 to 5000 BP. Lichenometry and radiocarbon dates on peat and buried organic horizons delimit a detailed Neoglacial chronology. Of 46 outlet and corrie glaciers investigated, the oldest Neoglacial moraines are dated lichenometrically at 3200 ± 600 BP. Subsequent advances terminated immediately prior to ca. 1650,780,350, and 65 yr BP, the most recent of which marked the most extensive ice coverage during the Neoglacial. The highest occurrence of lateral moraines from late Wisconsin advances of local and Laurentide ice suggest that at the late Wisconsin glacial maximum, depression of snowline varied from 450 m below present at the coast to 350 m below present level in the vicinity of the Penny Ice Cap. Moraines, surrounded by glacial ice and lying above the present steady-state ELA, suggest that during the Hypsithermal snowline was up to ca. 200 m above its present elevation. A radiometrically controlled reconstruction of relative summer paleotemperatures for the postglacial derived independently of lichenometry agrees well with the lichenometric age dating of moraines. The data suggest that between ca. 1650 and 900 BP climatic conditions were unfavorable for glacier growth, whereas the period ca. 800-65 yr BP was one of general glacial activity. During the last decade permanent snow cover has been increasing in the area. Previously reported data on climatic trends in the Canadian Arctic based on palynological analyses are similar to the chronology reported here.

A.A.

575. MILLER, G.H. 1975. Glacial and climatic history of northern Cumberland Peninsula, Baffin Island, Canada, during the last 10,000 years. Ph.D. Thesis, University of Colorado. 253 pp. Dissertation Abstracts International 36(5):2121B.

Climatic fluctuations have been reconstructed for the last 20,000 years based on i) the glacial moraine record, ii) inferred paleoenvironmental relationships of buried organic accumulations, iii) archaeological and paleobotanical evidence, and iv) the difference in response of two characteristic glacier types. The late Wisconsin climate was cold (summer temperatures >4°C below present values) and dry (<1/3 of present winter precipitation receipts). These conditions resulted from the highly zonal global circulation which persisted throughout the main glacial phases. When the global circulation returned to a non-glacial mode, increased cyclogenesis in Baffin Bay resulted in increased precipitation. Although this was probably accompanied by increased advection of relatively warm southern air, summer temperatures remained low due to the large amounts of remnant ice over much of northern North America, and the northeastern margin of the Laurentide Ice Sheet underwent a minor advance. By 8000 BP summer temperatures had increased substantially and ablation became dominant, and at about the same time the marine environment ameliorated. This local thermal maximum persisted from about 8000 to 5000 BP with maximum terrestrial temperatures reached between 7000 to 5000 BP.

The climatic reconstructions derived for Cumberland Peninsula broadly agree with other arctic paleoclimatic histories.

pD.A.I.

576. MILLER, G.H. 1976. Climatic and chronological differences between the northeastern and southern Laurentide margins and their implications to ice-core correlations. American Quaternary Association, Abstracts 4:28-29.

Three major Wisconsin till units have been recognized in the Clyde River area of eastern Baffin Island. Fossiliferous marine units formed during glacio-isostatic depression and recovery associated with each of these advances yield chronologic and marine environmental data. The late Wisconsin advance, represented by the Cockburn Moraine System near the fiord heads, remained at or near its maximum extent until ca. 8500 BP. The two older advances were considerably more extensive, both extending onto the continental shelf. The younger of these advances had receded behind the present coastline prior to 48,000 ^{14}C yr BP, the date on *in situ* molluscs in marine sediments overlying till of this advance. This till is separated from the older extensive Wisconsin advance by a substantial non-glacial interval. An interglacial soil-forming episode preceded the earliest Wisconsin advance.

Micro and macrofossil faunal assemblages in marine sediments associated with the two "early" Wisconsin tills are rich and contain species indicating that marine environments warmer than present prevailed during these most extensive Wisconsin Laurentide advances. In contrast, the terrestrial moraine record suggests that during the late Wisconsin stade, when the southern Laurentide margin attained or closely approximated its maximum extent, northern regions experienced restricted glacial activity, probably as a result of an arid, cold climatic regime. Shell collections dated between 8400 and 10,000 BP (the oldest late Wisconsin shells) contain an impoverished cold-water fauna, whereas younger collections are richer and include species of Subarctic affinity. This may be related to the reestablishment of the West Greenland Current about 8400 BP.

These data suggest arctic glaciations are primarily precipitation controlled, with the most extensive advances characterized by ameliorated marine episodes, terrestrial temperatures equal to or above present values and increased advection of moist southerly air into high latitudes. Episodes of extensive Laurentide Ice at southerly latitudes, however, correlate with periods of limited activity along the northern margins due to exceptionally cold, arid conditions under a more zonal global circulation regime. Although major arctic glaciations are apparently precipitation-controlled, the relatively small-scale events within the Neoglacial are more likely dependent on summer temperature variation.

Because of the differences in climatic controls and resultant glacial chronologies between the southern Laurentide margin and more northerly regions, it is imperative to first compare high latitude ice-core chronologies with the local stratigraphic sequence before attempting one to one correlations with fluctuations along the southern Laurentide margin.

A.A.

577. MILLER, G.H. 1976. Anomalous local glacier activity, Baffin Island, Canada: paleoclimatic implications. Geology 4(8):502-504.

Some local cirque glaciers on eastern Baffin Island were more extensive during the "Little Ice Age" than at any time in at least the past 34,000 yr and possibly the past 60,000 yr. The most reasonable paleoclimatic explanation of such anomalous glacier activity is that during the last glacial maximum in southern Canada, Arctic regions experienced diminished precipitation.

Local mountain glacier activity in the eastern Canadian Arctic is primarily controlled by precipitation variations; reduced mountain glacier activity during the Wisconsin Glaciation was a consequence of the prevailing arid, cold climate. Precipitation increases at the end of the Wisconsin Glaciation were accompanied by a parallel summer temperature rise, causing wide-spread recession of both Laurentide and local ice. The climatic deterioration of late Holocene time, occurring while precipitation remained relatively high, caused local glaciers to expand to their recent maxima.

A.A.$^{+}$

578. MILLER, G.H. 1980. Late Foxe glaciation of southern Baffin Island, N.W.T., Canada. Geological Society of America Bulletin 91(7):399-405.

A continental outlet glacier terminating in outer Frobisher Bay, southern Baffin Island, Arctic Canada, deposited the Hall moraine immediately prior to 10,760 yr B.P. (dated by C^{14}). This moraine and associated C^{14} dates provide the first documentation of a pre-Holocene late Foxe (late Wisconsin) ice advance from the eastern Canadian Arctic. A second moraine system deposited near the head of the bay is of Cockburn age (8,000 to 9,000 yr), and it correlates with the maximum late Foxe advance farther north on Baffin Island. A compilation of C^{14} dates related to the maximum late Foxe advance and marine paleoclimatology along 2,500 km of eastern Arctic coastline suggests a parallel but time-transgressive latitudinal relationship. There is considerable evidence for dominantly local ice accumulation centers and a prominent glacial advance between 11,000 and 10,000 yr B.P. from widely scattered sites surrounding the North Atlantic Ocean.

A.A.

579. MILLER, G.H., J.T. ANDREWS, and S.K. SHORT. 1977. The last interglacial-glacial cycle, Clyde foreland, Baffin Island, N.W.T.: stratigraphy, biostratigraphy, and chronology. Canadian Journal of Earth Sciences 14(12):2824-2857.

A study of the stratigraphic sequence (^{14}C and amino acid age control), marine bivalve faunal changes, and palynology of buried soils and organic-rich sediment collected from the Clyde Foreland Formation in the extensive cliff sections of the Clyde foreland, eastern Baffin Island, N.W.T., suggests the following last interglacial-Foxe (last glaciation) glacial-present interglacial sequence.

(1) Cape Christian Member (ca. 130,000 years BP?)
Consists of the Sledgepointer till overlain by the Cape Christian marine sediments. *In situ* molluscan fauna, collected from the marine sediment, contain a moderately warm bivalve assemblage. A well-developed soil that formed on the marine sediments (Cape Christian soil) contains an interglacial pollen assemblage dominated by dwarf birch. U-series dates of >115,000 and ca. 130,000 years BP on molluscs from the Cape Christian marine sediments suggest that they were deposited during the last interglaciation, here termed the Cape Christian Interglaciation. The development of a subarctic pollen assemblage in the Cape Christian soil has not been duplicated during the present interglaciation, suggesting higher summer temperatures and perhaps a duration well in excess of 10,000 years for the last interglaciation.

(2) Kuvinilk Member
Consists of fossiliferous marine sediments, locally divided by the Clyde till into upper and lower units. The Clyde till was deposited by the earliest and most extensive advance of the Foxe (last) Glaciation. Kuvinilk marine sediments both under- and overlying the Clyde till contain the pecten *Chlamys islandicus*, indicating that the outlet glacier advanced into a subarctic marine environment. Amino acid ratios from *in situ* pelecypod shells above and below the Clyde till are not statistically different, but contrast markedly with ratios obtained from the same species in the Cape Christian Member. Organic horizons within the Kuvinilk marine sediments contain a relatively rich pollen assemblage, although 'absolute' counts are low.

(3) Kogalu Member (>35,000 ^{14}C years BP)
Sediments of the Kogalu Member unconformably overlie those of the Kuvinilk Member, but are of a similar character. The dominant sediments are marine in origin, but in places are divided into upper and lower units by the Ayr Lake till. Amino acid ratios from *in situ* shells above and below the Ayr Lake till are indistinguishable, but substantially less than those in the Kuvinilk Member, suggesting the two members are separated by a considerable time interval. Radiocarbon dates on shells in the Kogalu marine sediments range from 33,000 to 47,700 years BP, but these may be only minimum estimates. The sea transgressed to a maximum level 70-80 m asl, coincident with the glacial maximum. Subarctic marine fauna of interstadial-interglacial character occur within the Kogalu marine sediments.

(4) Eglinton Member (10,000 years BP to present)
A major unconformity exists between the Kogalu and Eglinton Member. Ravenscraig marine sediments were deposited during an early Holocene marine trangression-regression cycle; the oldest dates on these sediments are ca. 10,000 years BP. Locally a vegetation mat occurs at the base or within the Ravenscraig unit. Pollen from these beds is sparse, but indicates a terrestrial vegetation assemblage as diverse as that of today. There is no evidence that Laurentide Ice reached the foreland during the last 30,000 years. Eolian sands that overlie a soil development on the marine sediments record a late Holocene climatic deterioration.

Pollen in organic-rich sediments at the base of, and within, the eolian sands record a vegetation shift in response to climatic change.

A.A.

580. **MILLER, G.H., R.S. BRADLEY, and J.T. ANDREWS. 1975. The glaciation level and lowest equilibrium line altitude in the High Canadian Arctic: maps and climatic interpretation. Arctic and Alpine Research 7(2):155-168.**

The glaciation level (GL) over the Queen Elizabeth Islands is highest over the main mountain areas. There are extremely steep gradients approaching 15 m km^{-1} along the northwestern margin of the archipelago where the glaciation level is very low (300 m a.s.l.). Although the glaciation level mirrors topography on a gross scale, at the finer level the relationship breaks down, probably because of the effect of the mountains on precipitation patterns. There appears to be a sharp decline in the elevation of the glaciation level between the Canadian islands and northwest Greenland. The elevation of the lowest equilibrium line altitudes (ELAs) are 100 to 200 m below the GL with a minimum elevation of 200 m a.s.l. The GL represents a theoretical surface where winter mass accumulation is equalled by summer mass ablation. The two primary controls on the elevation and gradient are, therefore, related to the pattern of winter snow accumulation and summer snowmelt. An analysis of available climatic data (one meteorological station per 100,000 km^2) is limited by the sparsity of records and the bias of existing stations to a coastal location. Nevertheless, on the shorter time scale, fluctuations in the height of the July freezing level correlate strongly with changes in glacier ELAs. However, there is little spatial correlation between decadal maps of July freezing levels and either GL or ELA surfaces.

A.A.

581. **MILLER, G.H., and A.S. DYKE. 1974. Proposed extent of Late Wisconsin Laurentide ice on eastern Baffin Island. Geology 2(3):125-130.**

Numerous raised glaciomarine deposits have been reported over the past 15 yr for which associated molluscan fauna have ^{14}C ages greater than 25,000 yr. For many of these deposits the shells are considered indigenous and there is no evidence of glacial overriding; therefore, they collectively delimit a maximum outer limit for younger advances. Within this limit only one moraine system exists for which related ^{14}C-dated deposits have finite ages. This moraine system, termed the Cockburn Moraine, is traceable with intermittent breaks from Cumberland Peninsula to the northern part of Baffin Island, and several studies suggest that ice remained at this moraine until about 8,000 yr BP. We propose that the Cockburn Moraine marks the maximum extent of late Wisconsin Laurentide ice in this area. South of Cumberland Peninsula, the Cockburn Moraine loses coherency; consequently, the location of the maximum stand of late Wisconsin ice in this region is less precise and is based on morphologic criteria and moraine segments with ages similar to the Cockburn Moraine farther north. It is most realistic to assume that decreased precipitation and temperatures in Arctic regions occurred during the pleniglacial, and that increased precipitation associated with renewed cyclogenesis in Baffin Bay during the late glacial phase allowed ice to remain at its maximum late Wisconsin stand well into the Holocene, despite increased temperatures. Although some of our arguments may be considered speculative, we feel a wide variety of independent lines of evidence support the form of the maximum ice margin and the basic conclusions of a restricted extent of ice on Baffin Island throughout the late Wisconsin. The glacial history of the northeastern margin of the Laurentide Ice Sheet is distinctly different from that of the southern margin, and it is doubtful that any one marginal area characterizes the ice sheet as a whole. Thus, correlating the Laurentide record with other Wisconsin stratigraphic sections must be done with caution.

A.C.

582. MILLER, G.H., and L.D. WILLIAMS. 1974. Late Wisconsin paleoclimate derived from a snowmelt program and variations in glacier response: eastern Baffin Island. Geological Society of America, Abstract with Programs 6(7):870.

Certain glaciers on Cumberland Peninsula, Baffin Island responded differently to late Quaternary climatic episodes. Glaciers which have an area/elevation profile with considerable area above 1000 m and narrow outlet glaciers (Type I) were equally extensive at the late Wisconsin and Neoglacial maxima. In contrast, other basins now occupied by restricted cirque glaciers contained extensive late Wisconsin glaciers which had different area/elevation profiles from the former case, with most area at moderate elevations (600 - 1000 m) (Type II). Using semi-empirical models relating glacier accumulation and ablation to gross climatic parameters it is possible to derive paleoclimatic estimates from the available data. To expand the Type II while maintaining, but not expanding, the Type I glaciers requires a snowline depression which will allow accumulation between 600 and 1000 m but decrease the accumulation above 1000 m (present ELA's are 800 - 900 m). This can be accomplished only by a summer temperature lowering (accumulation at lower elevations) and a precipitation decrease (decreased accumulation at high elevations). To determine the magnitude of the precipitation and temperature changes we developed a computerized mass balance program which calculated the net balance in 150 m elevational increments throughout the ablation season. The late Wisconsin climate was simulated by iterations with different precipitation and summer temperature values. The climatic simulation resulting in the nearest approximation to the observed late Wisconsin glacier responses was a climate equivalent to a summer temperature <4°C and annual precipitation <1/3 of present values. Thus the late Wisconsin climates along the northeastern and southern margins of the Laurentide Ice Sheet were dissimilar.

A.A.

583. MILLER, M.M., and J.H. ANDERSON. 1974. Out-of-phase Holocene climatic trends in the maritime and continental sectors of the Alaska-Canada Boundary Range. In: Quaternary Environments: Proceedings of a Symposium. Edited by: W.C. Mahaney. First York University Symposium on Quaternary Research. Geographical Monographs No. 5:33-58.

Comparative field studies of Quaternary glacial sequences and palynological profiles in kettle-hole bogs are described with respect to the coastal and interior flanks of the Alaska-Canada Boundary Range on a transect from Juneau, Alaska (Taku District) to Atlin, B.C. (Cassiar District). Special attention is given to the problem of out-of-phase glacio-climatic fluctuations in the maritime versus continental sectors of this Cordilleran region, within the framework of secular changes since Valders time...ca., 10,5000 to 11,000 yrs BP.

Based on radiocarbon dating of key horizons in the stratigraphic sequence, a table of climatic trends is noted for each region where today the mean annual sea-level precipitation regimes are 228 cm (in the temperate Sitka spruce and hemlock forest of the Juneau sector) and 25 cm (in the dry semi-arid white spruce and pine forests of the Atlin sector). References to "warmer and drier" and "warmer and wetter" designate precipitation regimes in each sector which characterized a period of increased storminess in the Thermal Maximum. All other adjectives (e.g. "warm", "cool") are relative to the respective Thermal Maximum conditions in each sector. The climatic characterizations are interpreted as follows:

	INTERVAL, YEARS B.P.	ATLIN (CASSIAR) DISTRICT	TAKU (JUNEAU) DISTRICT
	0 - 750	warm-wet	warmer-drier
	2,500 - 750	cold-dry (decreased storminess)	cooler-wetter cooling-wetting
	3,250 - 3,500	warm-wet	maximum warmth and dryness
	5,500 - 3,250	warmer-wetter (increased storminess)	maximum warmth and dryness relative warming-drying
Thermal Maximum	8,000 - 5,500	warm-wet	cool-moist
	9,000 - 8,000	cool-dry	relative warming-drying
	10,000 - 9,000	cooler-drier	cooler-wetter
	10,500 - 10,000	cool-dry	coldest
	11,000 - 10,500	cooler-drier	coldest (Valders equiv.)

The significance of this climatic sequence is discussed in terms of secular shifts in the Arctic Front and related storm path positions along the North Pacific Coast during the Holocene. Corroborating information is introduced from known variations of glaciers in this region since A.D. 1500 and from analyses of meteorological trends in the coastal sector where relatively continuous records have beeen maintained since A.D. 1840.

A.A.

584. MILLER, N.G., and R.R. IRELAND. 1978. A floristic account of the bryophytes of Bathurst Island, Arctic Canada. Farlow Herbarium of Harvard University, Occasional Paper 13:1-38.

Based primarily on collections made by the authors in 1973 and 1974, the bryophyte flora of the central part of Bathurst Island (ca. 75°43'N, 98°25'W), Northwest Territories, Canada, is reported to consist of 21 species of Hepaticae (including 4 represented by varieties) and 112 species of Musci (11 of which are represented by one or more varieties).

Although the occurrence of North Temperate Zone species of bryophytes in the Arctic has been used as evidence for postulating that certain areas escaped Pleistocene glaciation, the central part of Bathurst Island clearly shows the effects of both glacier activity and postglacial marine submergence (Blake, 1974a). Polar Bear Pass, the valley in which the reseach station is situated, was flooded by sea water to a depth exceeding 45 m beginning about 8500 years ago. The valley remained water filled, though at progressively lower levels, until approximately 4500 years ago, at which time the northern and southern portions of the island became joined. The collecting site for *Seligeria campylopoda* was the first beach ridge above the tundra meadow that now fills part of Polar Bear Pass. This beach was exposed perhaps 5000 years ago. The collection of *Pterygoneurum ovatum* was made in the upland north of the Pass. Deglaciation of Bathurst Island is believed to have begun prior to 10,000 years ago and by 9000 B.P. extensive areas were ice-free (Blake, 1964). Thus, the occurrence of both species reflects immigration at some time(s) during the Postglacial.

pA.A.+

585. MOCK, S.J., and W.D. HIBLER,III. 1976. The 20-yr oscillation in eastern North American temperature records. Nature 261(5560):484-486.

...we have examined January temperature records for 19 stations in eastern North America. Our results show that: first, a pervasive 20-yr peak exists in the spectra of January temperatures in eastern Canada and the United States; secondly, the 20-yr oscillation was largely in phase over this region until approximately 1960; and thirdly, the predictability of this oscillation is, at best, only marginal.

Excerpt

586. MODE, W.N. 1978. Preliminary Holocene pollen stratigraphy, Clyde Foreland, Baffin Island. American Quaternary Association, National Conference, Abstracts 5:172.

Pollen analysis of lacustrine sediment, underlain by littoral sand, reveals a sequence which begins during a period of optimum climate, shown by high amounts of shrub *Betula* pollen in the basal sediments. Though no dates have yet been received, dated shorelines within a few km and at the same altitude are 5000-6000 C^{14} years old, and this is the maximum expected age of the basal lake sediments.

Relative and "absolute" pollen diagrams suggest five zones. The basal zone, from 125-100 cm, can be termed the dwarf *Betula* zone because of its high *Betula* percentages (18-33%). From 95 to 60 cm, *Betula* percentages drop to very low levels while Poaceae and then *Salix* replace it as the dominant taxa. These two basal zones also feature the highest spore percentages in the core and this birch-lycopod-fern assemblage seems to have no modern analogue.

The upper three zones are all dominated by *Salix* (and to a lesser extent Poaceae), and assemblages are similar to those of modern pollen deposition in the area. From 50-55 cm, *Salix* is near its highest values (54-55%), but in the next zone above (45-25 cm), *Salix* decreases and is largely replaced by Poaceae, but also by slightly increased *Betula* percentages (6-10%), and by the highest *Alnus* (3-14%) of the core. These two zones also have the highest Ericaceae and Cyperaceae values of the core. In the uppermost zone (1-20 cm), *Salix* again dominates (49-61%) and Poaceae is also important (12-24%).

Though the timing is not yet known, it is likely that the basal *Betula* zone represents the period of optimum climate of the Holocene, when dwarf birch was growing near the site. The northern limit of dwarf birch on Baffin Island is now 400-450 km south of Clyde, and the upper four zones of the pollen diagram represent the deterioration of climate following the optimum during which birch presumably migrated south. The pollen zone from 45-25 cm with its increased *Alnus* and *Betula*, may represent a reversal of the general climatic deterioration.

A.A.

587. MOLFINO, B., N.G. KIPP, and J.J. MORLEY. 1982. Comparison of Foraminiferal, Coccolithophorid, and Radiolarian paleotemperature equations: assemblage coherency and estimate concordancy. Quaternary Research 17(3):279-313.

The Imbrie-Kipp method of paleotemperature estimation is rigorously tested by comparing Atlantic temperature equations independently derived from the microfossils of three biotic groups: the Foraminifera, Coccolithophorida, and Radiolaria. This method consists of two steps: factor analysis of the modern sea-bed data of the individual groups which resolves discrete biogeographic assemblages and regression analysis of the modern assemblage data with observed sea-surface temperature data to obtain paleotemperature equations. Assemblage biogeography shows a simple subdivision into warm (low latitude) and cold (high latitude) for all biotic groups. Between biotic groups there is greater similarity among high-latitude assemblages than low-latitude ones. Correlating the assemblage data with observed sea-surface temperatures to produce temperature distribution patterns shows differences of less than 2°C in their optimum and critical temperatures. Regression analysis produced accurate temperature equations for each biotic group, all with standard errors of estimate of less than or equal to 2°C. Multiple correlation coefficients were all greater than 0.970. Applying these equations to two multiple biotic data sets (the modern and ice-age sea-bed data) and comparing their temperature estimates using the standard error pooled, shows over 87% concordancy for both data sets. Unlike the modern data, the discordancy among temperature estimates of the ice-age data shows a distinct geographic distribution; its cause is believed to be oceanographic, a difference in the water-mass structure between the modern and ice-age ocean.

A.A.

588. MOODIE, D.W. 1977. The Hudson's Bay Company's Archives: a resource for historical geography. Canadian Geographer 21(3):268-274.

The author describes the nature and content of the Hudson's Bay Company's Archives (300 years old) which includes considerable information on climate.

L.G.

589. MOODIE, D.W., and A.J.W. CATCHPOLE. 1975. Environmental data from historical documents by content analysis: freeze-up and break-up of estuaries on Hudson Bay 1714-1871. Manitoba Geographical Studies 5:1-119.

This study uses the method of content analysis to identify dates of freeze-up and break-up from historical descriptions of these events. ... Its general purpose, therefore, is to demonstrate the use of content analysis as a method capable of yielding objective and valid environmental data from descriptive historical sources. Although the specific procedures employed in the study relate to the reconstruction of dates of freeze-up and break-up, they can be modified for use in any environmental research into descriptive, historical accounts.

Chapter I. ... briefly examines the general problems that confront the environmental scientist in historical research and on the other hand, it shows that certain methodological characteristics of content analysis recommend it as more suitable for the solution of these problems than traditional methods of historical investigation. Chapter II is concerned with the nature of content analysis and describes the terms and procedures of the methodology as it has been applied in this study. Subsequent chapters are devoted to a step-by-step application of the method to historical descriptions of freeze-up and break-up of four river estuaries on Hudson Bay in the eighteenth and nineteenth centuries. The descriptions are derived from daily records by personnel of the Hudson's Bay Company during this period, and relate to the estuaries of the Moose, Albany, Hayes and Churchill Rivers.

Chapter III describes and assesses contemporary standards and norms for the observation of freeze-up and break-up in Canada. In Chapter IV, content analysis frequency counts are used to establish the degree to which contemporary standards and criteria can be applied to the historical observations made by the Hudson's Bay Company journalists. The results of these investigations are combined in Chapter V to establish the procedures for retrieving the dates of freeze-up and break-up from the documents. This requires posing the questions that are to be put to the documents in the form of explicit categories of analysis, and devising rules whereby the retrieval of the requisite information via the categories is to be achieved. In Chapter VI, these procedures are implemented on a sample of the historical accounts in order to test the reliability or objectivity of the method.

Following the reliability testing, a full-scale analysis was conducted to retrieve the dates from the entire body of manuscript accounts. The problem of validating these dates is discussed in the first part of Chapter VII and, in the second part, validity tests are conducted upon certain types of dates selected for this purpose. Finally, a list of the selected dates of freeze-up and break-up embracing the period 1714-1871 is appended for the estuaries of the Moose, Albany, Hayes and Churchill Rivers.

A.I.

590. MOODIE, D.W., and A.J.W. CATCHPOLE. 1976. Valid climatological data from historical sources by content analysis. Science 193(4247):51-53.

Content analysis is used to derive dates of freeze-up and break-up from historical descriptions of river estuaries on Hudson Bay between 1714 and 1871. Validity testing of these dates indicates that they are comparable with modern data. It is thus proposed that the method affords potential for the systematic retrieval of a broad array of environmental data from the historical past.

A.A.

591. MOORE, T.C., Jr. 1973. Late Pleistocene-Holocene oceanographic changes in the Northeastern Pacific. Quaternary Research 3(1):99-109.

The distributions of the radiolarian assemblages in the Northeastern Pacific Ocean were determined and correlated with the average summer temperature of the near surface waters of this region. These assemblages were compared with those in three sediment cores taken beneath the Transition Zone waters. This comparison indicates that the assemblage off Oregon at the last maximum cold interval (24,000 yr B.P.) was like that now found off southern Alaska. The correlation of the radiolarian assemblages with temperature gives an estimate of 11°C for the average summer temperature at that time. This is approximately 4°C cooler than present day conditions in the area. Superimposed on the general warming trend that began 24,000 ya, there are minor oscillations in the assemblages which correspond to estimates of temperature change of about 2°C in the Pleistocene and about 1°C in the Holocene. In the Holocene, these minor warm intervals appear to be approximately synchronous with advances in mountain glaciers.

A.A.

592. MORGAN, A. 1975. Fossil beetle assemblages from the Early Wisconsinan Scarborough Formation, Toronto, Canada. Quaternary Non-marine Paleoecology Conference, University of Waterloo, Waterloo. Program and Abstracts.

Samples of detrital organic material were collected in a vertical sequence through the Scarborough Formation of the Scarborough Bluffs, east of Toronto along the shore of Lake Ontario. The samples were taken at varying intervals throughout the lower silt and clay unit at Cudia Park. The upper deltaic sand unit was randomly sampled between the Cudia Park and the Seminary sections wherever detrital lenses were available.

The organic material contained large numbers of fossil invertebrates such as caddisflies, midges, flies, bugs, ostracods, mites and spiders, but predominantly beetles. About 100 taxa of beetles have been found, 30 of which have been identified specifically. No extinct species were recognised with certainty, contrary to Scudders' findings described in a series of papers around 1900.

The faunal assemblages show no distinct differences through the sequence, indicating that the environmental parameters remained more or less constant during this Early Wisconsinan period. Several species now live on open tundra, some are distributed quite widely in North America, but the majority find conditions acceptable near the northern limits of the boreal forest. This suggests that the tree line was probably close to the Toronto area at the time the Scarborough Formation was deposited and that there was a sub-arctic climate.

A.A.

593. MORGAN, A., and A.V. MORGAN. 1976. Climatic interpretations from the fossil insect faunas of the Don and Scarborough formations, Toronto, Ontario, Canada. Geological Society of America, Abstracts with Programs 8(6):1020.

The fossil insects of the Don and Scarborough formations in Toronto indicate that a climatic deterioration occurred between the deposition of the two sequences. Unfortunately sites containing transitional faunas between the Sangamon Don beds and the Early Wisconsin Scarborough deposits have not yet been located, and the rapidity of the change is uncertain. The presence of fossil insects from the Don Valley Brickyard at the Scarborough Bluffs has been known for about 100 years, but the beetles were thought to be extinct. Fresh exposures of detrital organic material have been collected during the past six field seasons and a moderately well-preserved beetle fauna has been recovered from both localities. A re-examination of the fossil faunas has revealed that all the species are living today, but in widely differing geographic localities. The ecological interpretation of the Don fauna indicates a deciduous forest environment beside a large, slowly moving, well vegetated river flowing into a shallow lake embayment. The Scarborough insects, however, lived near the northern limits of the boreal forest with patchy, open tundra nearby. The mean annual temperature at the time that the Don beds were deposited was probably similar to that of the Toronto area today, about 4.5 to 7.5°C (40 to 45°F). The Scarborough beetle fauna indicates a much cooler environment with a mean annual temperature between -9.5° to -6.5°C (15 to 20°F).

A.A.

594. MORGAN, A.V. 1969. Intraformational periglacial structures in the Nose Hill gravels and sands, Calgary, Alberta, Canada. Journal of Geology 77(3):358-364.

A gravel and sand sequence at Calgary, Alberta, resting unconformably on Paskapoo sandstone and overlain by a late Wisconsin till, has within it two distinct horizons of structures attributable to periglacial activity. The lower horizon shows involutions and deranged and frost-shattered pebbles, while the upper horizon shows fossil ice wedges. A periglacial environment probably existed in southwestern Alberta at least twice during the gravel and sand deposition, and the sequence is probably of Pleistocene age, although predating the earliest Laurentide ice advance in the area. The average annual temperature in the Calgary area was approximately 9°-14°C cooler than at present.

A.A.

595. MORGAN, A.V. 1972. Late Wisconsinan ice-wedge polygons near Kitchener, Ontario, Canada. Canadian Journal of Earth Sciences 9(6):607-617.

Reconnaissance from a light aircraft has revealed areas of polygonal ground east of Kitchener, Ontario. Examination of aerial-photographs of the same region has shown additional polygons all developed upon Port Stanley II Till. Trenching of a polygon has exposed wedge-shaped sand and gravel infilled structures interpreted as ice-wedge casts. The wedges are believed to have been active prior to 13 000 years B.P., probably under tundra conditions, with mean annual air temperatures some 25°F (13-14°C) cooler than present.

A.A.

596. MORGAN, A.V., R.F. MILLER, and A. MORGAN. 1982. Paleoenvironmental reconstruction of southwestern Ontario between 11,000 and 10,000 yrs. B.P. using fossil insects as indicators. (North American Paleontological Convention III, Abstracts of Papers). Journal of Paleontology 56(2)(supplement):19.

Seven fossil insect localities from southern Ontario, and one site in northwestern New York, have been used to provide an environmental reconstruction of the region around the time of the palynological spruce-pine transition. Five of the sites are positioned near or at the margins of major lakes which formerly occupied the region. The Parkhill (*ca.* 10,850 yr. B.P.), Eighteen Mile River (*ca.* 10,600) and Wales (*ca.* 10,300) sites were adjacent to Glacial Lake Algonquin, while the Lockport Gulf (*ca.* 10,900 and younger) and Peatsah (*ca.* 10,750) sites were located beside the margin of Early Lake Ontario. The remaining localities are lacustrine sequences of marls at Gage St. (>11,000-<10,000) and Little Lake (*ca.* 10,000); while the Brampton Site (>11,000-<10,000) is principally composed of woody peat. Analyses of the faunas suggest regionally high temperatures (*ca.* 16° to 18°C) for sites inland from Lake Algonquin, but localised environments appear to have provided cooler habitats for certain species living in areas adjacent to Lake Algonquin and Early Lake Ontario. There appears to be no insect evidence for any major climatic change during the transition between spruce dominant and pine dominant vegetation seen in the pollen profiles of the region.

A.A.

597. MORGAN, A.V., and A. MORGAN. 1981. Paleoentomological methods of reconstructing paleoclimate with reference to interglacial and interstadial insect faunas of southern Ontario. In: Quaternary Paleoclimate. Edited by: W.C. Mahaney. Geo Abstracts, Norwich. pp. 173-192.

A number of working hypotheses have been established and refined, and insects are now being used as exceptionally sensitive indicators of climatic change.

In North America the interpretation of climatic change has been limited to research during the last decade, and the analyses of stenothermic categories have shown considerable temperature differences between Sangamonian, early Wisconsinan and middle Wisconsinan deposits in the Toronto region.

Each of the faunas described [from the above deposits] can be placed into a climatic 'bracket' depending upon the relationship of the indicator species to the different categories. Thus the beetles from the top of the Don Formation apparently indicate July temperatures of about 20° to 21°C; the Scarborough Formation beetles suggest July temperatures of some 11° or 12°C, and the Beaver Valley beetles, July temperatures which probably did not rise much above 10°C. Estimation of mean annual temperatures are far more difficult, especially for the colder faunas; however, the Don assemblage probably is indicative of a mean annual temperature of about 5°-7°C.

pA.A.+

598. MÖRNER, N.-A. 1971. The Plum Point Interstadial: age, climate and subdivision. Canadian Journal of Earth Sciences 8(11):1423-1431.

Plum Point Interstadial deposits in Scarborough Bluffs, Toronto, include a layer of unvarved sandy sediments, which indicates relative low lake level, with the ice margin some distance away, probably north of the Ontario basin proper. Radiocarbon dates above and below this layer suggest an age of the most temperate part of the Plum Point Interstadial of 32 000-28 300 B.P. i.e. exactly the same age as for the Denekamp Interstadial in Europe. The Plum Point Interstadial in a broad sense can be subdivided, climatically, into three units.

A.A.

599. MÖRNER, N.-A. 1971. The position of the ocean level during the interstadial at about 30 000 B.P. A discussion from a climatic-glaciologic point of view. Canadian Journal of Earth Sciences 8(1):132-143.

Several ^{14}C-dated marine shells (and exceptionally even estuarine peat) found at about the present sea level - just below to just above - in different regions of the world suggest a eustatic high stand at about 30 000 B.P.; however, this appears to be incorrect for two main reasons.

1. From a climatic-glaciologic point of view the interstadial at about 30 000 B.P. (Denekamp, Plum Point, etc.) must correspond to an ocean level far below the present (or roughly corresponding to the Late Glacial one at about 12 000 B.P.).

2. Contamination of a sample containing dead or almost dead carbon by 1-5% modern carbon will give the sample an apparent age of 36 000-24 000 B.P.

A.A.

600. MÖRNER, N.-A. 1977. Climatic framework of the end of the Pleistocene and the Holocene: paleoclimatic variations during the last 35,000 years. Géographie physique et Quaternaire 31(1-2):23-35.

Paleoclimatic changes are recorded by several methods. These fluctuations follow cycles of different rank and duration. Seen in a global scale, there can be little doubt that the climatic changes generally occurred simultaneously all over the globe. This does not mean that they are equally expressed; on the contrary, these changes are quite locally expressed. It is the coincidence in time that reveals the global climatic background. The Gothenburg Magnetic Excursion and Flip, characterized by Pacific VGP positions, provide a new tool for global correlations. The radiocarbon calibration scale is extended back at least to 10,000 BP via a new method based on shorelines and varves. Because of necessary good dating control, the present analysis is confined to the last 35,000 years. 1) Correlations of global climatic data indicate a worldwide synchronism without any detectable time-lag between different variables. 2) Climatic, glacial and eustatic fluctuations follow four main cycles: a 21,000-yr cycle, a 5250-yr cycle, an irregular 1000-3600-yr cycle, an irregular 230-1000-yr cycle. 3) Geoidal-eustasy is a new factor which is related to fundamental geophysical processes. 4) Integrated studies of multiple parameters in the same long Holocene sediment cores have revealed a detailed correlation between climatic changes, eustatic changes, paleomagnetic intensity and polarity changes, atmospheric ^{14}C production changes, etc., suggesting a mutual origin. 5) The main cause of the 5250-yr cycle and the two irregular cycles seems to be changes of the core/mantle coupling and interface according to two different systems. This explains the correlations established and the absence of any time-lag.

A.A.

601. MÖRNER, N.-A., and A. DREIMANIS. 1973. The Erie Interstade. Geological Society of America Memoir 136:107-134.

The type section for the Erie Interstade shows a well-developed beach between two layers of offshore sands. The section is underlain by a major late Wisconsin till, the Catfish Creek Till, and is overlain by the Port Stanley Till. The position of the buried beach 3 to 4 m above present Lake Erie level indicates that the interstadial lake, here named Lake Leverett, was lower than previously estimated and that it drained eastward, probably via the Mohawk Lowland, during an ice recession into the Ontario Basin.

The Erie Interstade correlates well with a world-wide amelioration of the climate at about 15,500 yrs B.P. that separates two glacial maxima of the late Wisconsin-Weichselian, the older 20,000 to 17,000 yrs B.P. and the younger 14,800 to 14,400 yrs B.P.

A.A.

602. MORRISON, A. 1970. Pollen diagrams from interior Labrador. Canadian Journal of Botany 48(11):1957-1975.

Six pollen zones can be distinguished in interior Labrador. The earlier zones represent the primary succession of vegetation from bare ground to boreal woodland or forest, which occupied about 500 years between 5700 and 5200 B.P. There have been only minor fluctuations in the nature of the vegetation since 5200 B.P. Radiocarbon dates show that the zones are contemporaneous over that part of the Lake Plateau within the Churchill River watershed, but similar vegetation changes occurred 1000 years earlier in the Kaniapiskau basin, further north, in New Quebec. These two areas must have been freed of a cover of glacier ice or lake waters immediately before 5700 B.P. and 6700 B.P. respectively.

A.A.

603. MOTT, R.J. 1968. A radiocarbon-dated marine algal bed of the Champlain Sea episode near Ottawa, Ontario. Canadian Journal of Earth Sciences 5:319-324.

A bed of marine algae (seaweed) in a sand pit in Champlain Sea sediments southwest of Ottawa, Ontario, was dated by the radiocarbon method and gave an age of 10,800 ± 150 years (GSC-570). Marine shells from above and below the algal bed gave radiocarbon ages of 10,620 ±200 years (GSC-587) and 10,880 ±160 years (GSC-588) respectively.

The algae and underlying shells have been excellently preserved as a result of rapid burial following deposition and remaining beneath a high water table. The similarity of the radiocarbon dates on the algae and on the shells above and below, and with previous dates on shells from other Champlain Sea deposits indicates the reliability of these shell dates.

A.A.

604. MOTT, R.J. 1969. Palynological studies in central Saskatchewan; contemporary pollen spectra from surface samples. Geological Survey of Canada Paper 69-32:1-13.

Saskatchewan lies within two vegetational zones: the grasslands or prairie, and the boreal forest. Surface samples collected as part of a study of the late-glacial and postglacial geochronology and vegetational and climatic history of central Saskatchewan, yielded contemporary pollen spectra characteristic of both zones. Pollen spectra typical of the grasslands contained 60 to 70 per cent herbs, 25 to 35 per cent trees, and 5 per cent or less shrubs. Spectra from the forested areas showed varying amounts of tree pollen, typically in excess of 50 per cent, with herb pollen usually less than 35 per cent. Although not as readily distinguishable by their pollen spectra, some sections of the Boreal Forest Region, as defined by Rowe (1959), were found to have discernible pollen assemblages. In addition to the general relative proportions of tree, shrub and herb pollen, data on the abundance of individual genera are needed in order to differentiate these forest sections.

Detailed study of several long cores already obtained from Saskatchewan may determine the extent to which the present conclusions will be useful in outlining past vegetation zones. Preliminary results suggest that at least some of the pollen spectra discussed here are of diagnostic value.

A.A.+

605. MOTT, R.J. 1971. Palynology of a buried organic deposit, River Inhabitants, Cape Breton Island, Nova Scotia. Geological Survey of Canada Paper 71-1B:123-125.

The material collected is more than 39,000 yrs. old. The overlying sediment sequence is interpreted by Grant to represent: (1) periglacial deposition of colluvium and organic detritus; (2) proglacial deposition of outwash gravel, and (3) burial by tills of the last glaciation. The deposit is assigned to an early Wisconsin interstade. Pollen diagrams are presented, showing boreal forest assemblages dominated by *Picea* (spruce) and *Alnus* (alder), lesser amounts of *Pinus* (pine), and small percentages of *Betula* (birch) and *Abies* (fir).

L.G.

606. MOTT, R.J. 1973. Palynological studies in central Saskatchewan. Pollen stratigraphy from lake sediment sequences. Geological Survey of Canada Paper 72-49:1-18.

Lake sediment sequences from four sites in central Saskatchewan were studied as part of a project to determine the late-glacial and postglacial vegetational and climatic history of the area. Several radiocarbon dates help to outline chronology.

Boreal vegetation dominated by *Picea* invaded the area as the ice retreated northward. Progressively younger radiocarbon dates on the *Picea* zones, 11,560 ± 640 (GSC-648) at Prince Albert, 10,260 ± 170 (GSC-647) within Prince Albert National Park, and 8,520 ± 170 (GSC-643) near La Ronge, mark the migration northward. About 10,000 years B.P. a warmer and less humid climate caused grasslands to replace the boreal vegetation in the south and grasslands prevailed to the present in the Clearwater Lake area on the Missouri Coteau. Grassland vegetation also invaded the Prince Albert area and, although open grasslands did not extend as far north as the study site within Prince Albert National Park, a parkland type of environment may have existed for a short time. The grasslands retreated with the return of a cooler and more humid climate and a mixed wood forest developed in the Prince Albert National Park areas. In the La Ronge area the *Picea*-dominated vegetation gave way to a mixed wood forest and then, after about 6,000 ± 170 years B.P. (GSC-1335), a coniferous forest gradually developed.

A.A.

607. **MOTT, R.J. 1974. Modern pollen spectra from Labrador. Geological Survey of Canada Paper 74-1B:232-234.**

The Lake Plateau region of Labrador with its spruce woodland vegetation is characterized by modern pollen assemblages dominated by spruce and abundant birch, alder, sedge, and *Sphagnum*, with a variety of other taxa in lesser amounts. Similar assemblages have prevailed in the area over the past 4,000 to 5,000 years, indicating a type of vegetation similar to the present for this time period (Morrison, 1970).

A.S.

608. **MOTT, R.J. 1975. *Populus* in late-glacial pollen spectra. Quaternary Non-marine Paleoecology Conference, University of Waterloo, Waterloo. Program and Abstracts.**

Populus profiles in pollen diagrams have often been ignored or given little attention because of problems with identification and preservation. Modern surface spectra aid in the interpretation of fossil assemblages, but exact modern analogues have not been found. Recent studies from several localities have revealed peaks in *Populus* pollen in late-glacial and/or early Holocene spectra, and relative and absolute frequencies indicate that *Populus* may have played a significant role in the transition from tundra to forested conditions.

A.A.

609. **MOTT, R.J. 1975. Palynological studies of peat monoliths from L'Anse aux Meadows Norse site, Newfoundland. Geological Survey of Canada Paper 75-1A:451-454.**

The main conclusion that can be drawn from the pollen diagrams is that over the time span involved, that is over the last 1,800 to 2,000 years, there have been no drastic changes in the vegetation of the area.

Excerpt

610. **MOTT, R.J. 1975. Palynological studies of lake sediment profiles from southwestern New Brunswick. Canadian Journal of Earth Sciences 12(2):273-288.**

Lake sediment cores from two lakes yielded pollen profiles which reflect vegetational and climatic changes since deglaciation. Radiocarbon dates from specific levels outline the chronology. Correlation of pollen zones between the two profiles indicate the degree of error in the anomalously old dates from one of the sites. Total absolute pollen frequencies are used to aid in interpretation.

Following deglaciation a tundra environment prevailed until about 12,000 radiocarbon years B.P. This was followed by a transition zone in which *Betula* and *Populus* were abundant. About 12,000 years B.P. *Picea* increased markedly and remained a dominant part of the vegetation until 9500 years B.P. when *Pinus* and *Quercus* became prominent. *Tsuga* and various hardwood genera predominated after 6500 years B.P. An increase in *Picea* and decline in *Tsuga* and some hardwood genera produced the forests which prevailed when the area was settled.

Some indication of the climate that prevailed during the time encompassed by the New Brunswick profiles can be gained from the pollen data and the inferred vegetation. Following deglaciation the depauperate flora of herbs and shrubs indicating tundra conditions probably reflects a cool climate caused at least in part by the close proximity of the retreating ice sheet. Migration lag is a factor that is difficult to assess and the extant flora may not accurately represent the climate of the time especially if climatic changes occurred abruptly as suggested by Bryson and Wendland (1967).

Pollen assemblages and gradually increasing deposition rates about 11,300 years ago attest to a changing flora with more trees present. If the vegetation of the time is indicative of the climate then conditions similar to those of the Nichicun Lake area of north-central Quebec at the present time characterized the area. The great increase in pine pollen and the general increase in pollen deposition rates at the beginning of Zone 5 about 9500 radiocarbon years ago, point to further amelioration of the climate until in Zones 4 and 3 thermophilous hardwood genera were represented in greater amounts of pollen than at any other time before or since. In more recent times in southwestern New Brunswick, i.e., the last millenium, a return to cooler and more moist climate is indicated by an increase in spruce pollen and decline in hemlock and hardwood genera.

The classical sequence of a warming trend to a maximum in warmth and dryness followed by a return to a somewhat cooler and more moist condition has been discussed in more detail by Davis (1969) but many factors await further clarification. The role of climate and migration rates have not been sorted out satisfactorily and such parameters as fire, disease, drought and others have hardly been dealt with.

A.A. and pA.C.

611. MOTT, R.J. 1976. A Holocene pollen profile from the Sept-Îles area, Québec. Naturaliste Canadien 103(5):457-467.

The boreal forest of the Sept-Îles area has prevailed for at least the last several thousand years with fluctuations in the forest composition but not in the individual species involved. The earliest forest community inferred from the "LD" Lake pollen profile consisted of spruce, balsam, fir, birch and alder as the dominants with alder more abundant than at the present time and spruce and birch less abundant. After about 7000 years B.P. balsam fir became considerably more abundant, partly at the expense of alder and partly as the result of a general proliferation of species; it dominated until about 6400 years B.P. Spruce and birch then became more abundant and this forest type, with some minor fluctuations, prevailed to the present.

The replacement of balsam fir by spruce and birch accompanied by increased pine pollen is somewhat anomalous in that balsam fir increases usually follow declines in spruce (Richard, 1971; Richard and Poulin, 1976). A return to spruce would suggest a deterioration of the climate while increased pine indicates the opposite. Richard (1973), in a profile from a site near Kenogami, encountered increased spruce following a decline in balsam fir for the same time interval and attributed it to a deterioration of the climate. This does not seem to be the explanation at "LD" Lake. ...

A.A.+

612. MOTT, R.J. 1977. Late-Pleistocene and Holocene palynology in southeastern Québec. Géographie physique et Quaternaire 31(1-2):139-149.

Several relative and absolute pollen profiles from the Appalachian region outline the vegetational history of the region. The earliest reliable date of 11,200 radiocarbon years

BP, from the watershed area of the Mégantic Hills on the Québec-Maine border, dates the spruce pollen maximum, indicative of spruce woodland conditions. A second site in the same area shows tundra conditions existed prior to this time, but no radiocarbon dates are available to indicate the length of time these conditions persisted. About 10,000 radiocarbon years BP or less, the character of the vegetation changed and closed forest conditions prevailed. Spruce was still present, but balsam fir and birch increased and other deciduous species appeared. The continued increase in thermophilous deciduous species and hemlock and white pine during early-and mid-Holocene resulted in forests in which these taxa were more prominent than at present. An increase in spruce and decline in thermophilous taxa in the last few millenia produced the extant forest types.

A.A.

613. MOTT, R.J. 1978. *Populus* in late-Pleistocene pollen spectra. Canadian Journal of Botany 56(8):1021-1031.

Populus profiles in pollen diagrams have often been ignored or given little attention because of problems with identification and preservation. Modern surface spectra aid in the interpretation of fossil assemblages, but exact modern analogues have not been found. Recent studies from several localities in Canada have revealed peaks in *Populus* pollen in late-Pleistocene and (or) early-Holocene spectra, and relative and absolute frequencies indicate that *Populus* may have played a significant role in the transition from tundra to forested conditions.

A.A.

614. MOTT, R.J., T.W. ANDERSON, and J.V. MATTHEWS, Jr. 1981. Late-glacial paleoenvironments of sites bordering the Champlain Sea based on pollen and macrofossil evidence. In: Quaternary Paleoclimate. Edited by: W.C. Mahaney. Geo Abstracts, Norwich. pp. 129-171.

The landscape bordering the Champlain Sea in the St. Eugene area about 11,050 years BP supported tundra vegetation and the climate was probably considerably colder than the present in that area. To the north, between the sea and the ice front standing at the St. Narcisse moraine, a polar desert with discontinuous herbaceous vegetation prevailed. Trees had invaded the Appalachians to the south but had not formed closed forests, and the island formed by the peak of Mont St. Hilaire probably had sparse shrub tundra vegetation with some spruce trees. By 10,100 years BP the climate had improved considerably. Trees were more abundant and of greater variety on Mont St. Hilaire and throughout southeastern Quebec giving the landscape an open boreal forest character. To the north of the diminished Champlain Sea, shrub vegetation prevailed.

A.S.

615. MOTT, R.J., T.W. ANDERSON, and J.V. MATTHEWS, Jr. 1982. Pollen macrofossil study of an interglacial deposit in Nova Scotia. Géographie physique et Quaternaire 36(1-2):197-208.

Pollen, plant macrofossil and arthropod (mainly beetle) remains from a 2-m exposure of peat and organic clay, underlain by a gray till-like deposit and overlain by more than 20-m of red till, from Milford Gypsum Quarry, East Milford, Nova Scotia were studied. The integrated fossil evidence, combined with a radiocarbon date of >50,000 years B.P. (GSC-1642) on wood (*Larix* sp.) from the organic sediments, leads to the conclusion that the latter part of an interglacial interval, probably the Sangamon, is represented.

The latter part of this interglacial was dominated by a mixed hardwood forest (*Fagus, Ulnus, Acer, Quercus* and *Tilia*) - attesting to a climate at least as warm as present in the area. Climatic conditions then began to deteriorate and the hardwood forest was replaced by a mixed forest (*Betula* became dominant), which in turn changed to a coniferous forest (*Picea* sp. and *Abies balsamea* predominating). Other floras of possible Sangamon age from northeastern North America are mentioned.

C.R.H.

616. MOTT, R.J., and M. CAMFIELD. 1969. Palynological studies in the Ottawa area. Geological Survey of Canada Paper 69-38:1-16.

One large bog and five buried bog deposits were sampled in the Ottawa area. Radiocarbon dates, obtained near the base of four of these sections, ranged from about 7,650 years B.P. to roughly 8,830 years B.P.

Pollen analysis of samples from the six sites revealed four zones, Terasmae's zone IV being the oldest. At only two of the sites were all four zones present; at the others, all or part of some zone was missing.

A.A.

617. MOTT, R.J., and L.D. FARLEY-GILL. 1978. A late-Quaternary pollen profile from Woodstock, Ontario. Canadian Journal of Earth Sciences 15(7):1101-1111.

Maplehurst Lake, situated in a former interlobate zone that was deglaciated relatively early compared to adjacent areas of southern Ontario, provides one of the more complete pollen records for the region.

Five radiocarbon dates allow determination of sedimentation rates and hence pollen influx rates. Both relative percentage and pollen influx values outline a vegetational history that began prior to 12,000 years BP with a herb pollen zone representative of tundra conditions. This was followed by invasion of spruce that culminated in a spruce woodland environment which peaked about 11,200 years BP and then declined, to be replaced, beginning about 9500 years BP, by a closed mixed conifer-hardwood forest dominated by pine species. Hemlock replaced pine as the most abundant coniferous species about 7200 years BP. Hardwoods completely dominated the forest after 6400 years BP and beech, maple, oak, elm, and ash were prominent, associated with a wide variety of other deciduous genera. The deciduous hardwood forest prevailed without major change until recent times when the forests where largely removed for agriculture. Ragweed, grasses, and other weed taxa indicative of agricultural activity characterize the pollen spectra of this most recent interval. This sequence of events parallels those found at sites throughout the Great Lakes region, New England, and Maritime Canada and adds to the knowledge of migration rates, succession, chronology, and climate of northeastern North America.

A.A.

618. MOTT, R.J., and L.E. JACKSON, Jr. 1982. An 18 000-year palynological record from the southern Alberta segment of the classical Wisconsinan "Ice-free Corridor". Canadian Journal of Earth Sciences 19(3):504-513.

Radiocarbon dates of 18 300 ± 380 years BP (GSC-2668) and 18 400 ± 1090 years BP (GSC-2670) on moss fragments from the clay near the base of a core from Chalmers Bog, Alberta indicate that the classical Wisconsinan "Ice-free Corridor" was in existence in the foothills of southern Alberta by this time. Palynological studies show sparse, herbaceous, tundra-like vegetation probably prevailed at this time in the area surrounding the small lake formed in the abandoned glacial spillway. Later, shrubs became more prominent to form a shrub tundra environment. Sometime before 8220 years BP (GSC-2851) trees began to invade the area and the *Pinus contorta*-dominated coniferous forest extant in the area today began to form. Bog and fen vegetation invaded the shallow lake basin about this time as well to form the bog that occupies the basin to the present day.

A.A.

619. MOTT, R.J., and V.K. PREST. 1967. Stratigraphy and palynology of buried organic deposits from Cape Breton Island, Nova Scotia. Canadian Journal of Earth Sciences 4(4):709-724.

Pollen analysis of four non-glacial, sub-till deposits on Cape Breton Island, Nova Scotia, yielded pollen assemblages indicative of climates cooler than the present in that area. New radiocarbon dates from Hillsborough (>51 000 years), Bay St. Lawrence (>38 300), and Whycocomagh (>44 000 years) place the deposition of these deposits in pre-classical Wisconsin time. The Hillsborough and Whycocomagh deposits are considered to be time-equivalent based on pollen analysis. A lack of distinct asseblages at Bay St. Lawrence and Benacadie prohibits correlation with one another and with the Hillsborough and Whycocomagh beds. Inferences drawn from the pollen flora and the stratigraphy indicate an early Wisconsin interstadial age for these deposits rather than a Sangamon interglacial age. They are tentatively correlated with the St. Pierre interstade in Quebec.

The climate during this interval is best indicated by the Hillsborough assemblages. Although this site yields the longest record of the four, it does not necessarily represent the complete interval. Generally, cool, wet conditions prevailed throughout, as indicated by pollen assemblages dominated by *Abies, Picea, Alnus* and *Betula*. Minor fluctuations are indicated by changes in the relative abundances of various genera, but at no time did the climate become as warm as the present. Similarities with the present pollen assemblages from Newfoundland and other areas of the Boreal Forest Region can be seen in the Cape Breton Island assemblages.

A.A.$^{+}$

620. MUDIE, P.J. 1982. Pollen distribution in recent marine sediments, eastern Canada. Canadian Journal of Earth Sciences 19(4):729-747.

Analysis of 90 samples from coastal and continental shelf areas off eastern Canada betwen 42 and 69°N shows that Quaternary pollen and spores are present in recent marine muds throughout this region. Pollen and spore concentrations range from 50 000 to 100 grains per cm^3 and they decrease both offshore as a function of distance from vegetation sources and northwards as a function of lower vegetation density north of the summer Arctic Frontal Zones. Isopercentage contours show that maximum relative abundances of most palynomorphs occur in marine sediments adjacent to their regions of highest vegetation representation onshore. However, *Pinus* and *Picea* pollen tend to increase in percentage abundance with distance offshore. Presence of these tree pollen in marine sediments off Baffin Island implies that wind transport is an important pathway by which bisaccate pollen types enter the ocean, in addition to fluvial transport.

Q-mode factor analysis shows that four major factors account for 89% of the variance among the marine palynomorph samples, while two other factors (6% of the variance) apparently reflect selective transport of *Pinus* pollen or local over-representation of Gramineae. The major factor assemblages are: (1) Boreal Forest Assemblage, with high weightings of *Picea* and maximum loadings adjacent to the boreal forest, 48-54°N; (2) Arctic Assemblage, weighted by Rosaceae, Gramineae, and Cyperaceae, with maximum loadings off Baffin Island, 60-69°N; (3) Mixed Forest Assemblage, weighted by *Betula* tree pollen, *Picea glauca, Pinus strobus, Tsuga*, and temperate trees (e.g. *Quercus, Acer*), with maximum loadings in the southeast, 42-48°N; (4) Subarctic Assemblage, with high weightings of *Sphagum*, *Alnus*, and *Lycopodium*, and maximum loadings adjacent to forest-tundra and low arctic tundra, 54-60°N. These regional marine pollen assemblages are empirically related to contemporary climatic parameters, thus indicating the potential value of pollen analysis for direct correlation between Quaternary paleoclimatic records onshore and in marine areas bordering eastern Canada.

A.A.

621. MUDIE, P.J., and C.T. SCHAFER. 1976. Correlation and interpretation of palynological assemblages in replicate cores of marine sediment from Georges Bay, Nova Scotia. Maritime Sediments 12(3):100. (Abstract).

Two short, diver-retrieved cores from Georges Bay, 0.6 m long and spaced 4 m apart, were studied to determine if the pollen records in this marine bay could be used to correlate Recent terrestrial and marine paleoecological events. By applying a new palynormorph processing technique, both pollen and dinocyst evidence of environmental changes could be investigated. Arboreal pollen assemblages and weed pollen markers, including *Ambrosia, Rumex acetosella* and *Plantago lanceolata*, consistently indicate a post-European depositional history for the upper 30 cm of sediment. In contrast, pollen, cyst and radiocarbon evidence suggests that the lower half of the cores record a history of redistributed marine sediment that was originally deposited during a hypsithermal climatic interval.

A.A.

622. MÜLLER, F. 1962. Analysis of some stratigraphic observations and radiocarbon dates from two pingos in the Mackenzie Delta area, N.W.T. Arctic 15(4):278-288.

The Ibyuk Pingo is certainly considerably younger than the glacierization that produced the glacial deposits in its cover of sediments. ... Sedimentation ceased less than 12,000 years ago... It is estimated that this pingo is at the most 7,000 to 10,000 years old, i.e., of late Wisconsin age. ... It is presumed that conditions during the Hypsithermal permitted the continuance of aggradation of permafrost and thereby the growth of pingos.

The youngest layers of the covering sediments of the Sitiyok Pingo were deposited in a lake or swamp about 6,000 years ago, that is, during the Hypsithermal. The formation of the Sitiyok Pingo is therefore likely to have started with the marked general cooling of the climate that followed the Hypsithermal time, i.e, about 4,000 years ago. ...

There is ample evidence for a glacierization of the Ibyuk area and the environs of Tuktoyaktuk, but so far no such evidence has been found around the Sitiyok Pingo. In a brief reconnaissance to the northeast of Tuktoyaktuk no glacial remnants were observed except for one huge boulder near Toker Point, 20 km to the north of Sitiyok.

The glacial material contained in the sediment cover of the Ibyuk Pingo is certainly younger than 28,000 ± 2,000 years and older than 12,000 ± 300 years. It is estimated that the glacierization of the Mackenzie Delta area that produced the Ibyuk till lasted from 25,000 B.P. to 15,000 B.P., being therefore late Wisconsin.

pA.C.

623. MÜLLER, F. 1964. Evidence of climatic fluctuations on Axel Heiberg Island, Canadian Arctic Archipelago. McGill University, Montreal. 11 pp.

Reports detailed investigations 1959-1963 into the glaciology of the White, Thompson and Baby Glaciers. Glacier mass budgets calculated over four consecutive years are tabulated and diagrammed. From these and investigation of a deep firn profile, it is concluded that conditions since 1930 have produced an overall loss of ice mass. The snout of Thompson Glacier is advancing 20 m/yr due to accumulaton prior to this date. C-14 dating of willow roots from moraine-outwash interface indicates an early 18th century glacial advance but peat deposits show that this has not been more than 2 km in last 4000 yr. Datings of driftwood indicate a climatic optimum 6000 BP. Some evidence was found to confirm the extensive 20,000-10,000 BP glacierization of Fyles and traces an even larger Wisconsin ice maximum. In general, climatic fluctuations appear to have had a lesser amplitude than in temperate latitudes.

A.B.

624. NAIDU, A.S., T.C. MOWATT, D.B. HAWKINS, and D.W. HOOD. 1975. Clay mineralogy and geochemistry of some Arctic Ocean sediments: significance on paleoclimate interpretation. In: Climate of the Arctic. Edited by: G. Weller and S.A. Bowling. 24th Alaskan Science Conference. pp. 59-67.

Clay mineral and chemical compositions of contemporary marine sediments of the Arctic were analyzed by X-ray diffraction and atomic absorption spectrophotometry, respectively. The clay mineral assemblage of the Arctic Ocean sediments do not substantiate the scheme of latitudinal variations of clay minerals in world ocean sediments as suggested by some authors. Thus, interpretation of paleoclimate on the basis of clay mineral assemblages in ancient marine sediments must be made with extreme caution.

The Arctic Ocean deep-sea clays have a significant deficiency of Mn, Ca, Mg, Na, K, Rb, Co, Cu, Zn and Ni, as compared with nonpolar deep-sea clays. In view of the possibility that the difference in polar and nonpolar sediment chemistries may be related to regional differences in several nonclimatic factors as well as to regional climate, geochemical criteria have limited applicability as a paleoclimatic indicator. In the Asian-American Basin of the Arctic Ocean, where the sedimentation rate and source apparently have remained unchanged and the tectonic history has been stable over the Quaternary, it is tempting to surmise that in that region the post-Tertiary stratigraphic differences in sediment chemistries do reflect climatic variations.

A.A.

625. NAMBUDIRI, E.M.V., C.T. SHAY, and J.T. TELLER. 1979. Pollen stratigraphy of late Pleistocene and Holocene sediments from Lake Manitoba, Canada. Geological Society of America, Abstracts with Programs 11(5):253.

Pollen analyses of surface and deep core samples, recovered from Lake Manitoba, reveal the vegetational changes during late Pleistocene and Holocene times. Basal sediments were deposited in deep water near the western shores of Lake Agassiz. The late-glacial assemblage is dominated by *Picea* and *Pinus* together with Cyperaceae, *Artemisia*, *Betula*, and Chenopodiineae. *Picea* declines at about 10,000 BP while *Pinus* and Gramineae increase.

Reconstruction of the vegetation from these assemblages in the lower part of the core is complicated by very low pollen concentration and the presence of 60-80% pre-Quaternary microfossils. Recognition of *Aquilapollenites*, *Hystrichosphaeridium*, acritarchs, and dinoflagellates suggests a Cretaceous assemblage. This large influx is probably the result of active glacial erosion of Cretaceous bedrock in the region and of wave erosion of the extensive Cretaceous outcrops which formed the western lake margin during the early, Lake Agassiz, phase. The presence of Cretaceous palynomorphs indicates that dead carbon was incorporated into the sediment, and suggests that adjustments should be made to some ^{14}C dates. The gradual decline and subsequent disappearance of the Cretaceous component coincides with the retreat of Lake Agassiz which brought a more stable regional surface and a higher Holocene pollen influx. The rise in *Ambrosia* pollen, indicative of the inception of agricultural activity about 100 years ago, occurs at 35 cm in most cores.

A.A.

626. NAMIAS, J. 1981. Anatomy of Great Plains protracted heat waves. First Conference on Climate Variations of the American Meteorological Society, January 19-23, San Diego. Abstracts, p. 12.

Protracted heat waves and associated drought over the Great Plains of the United States, such as occurred in the summer of 1980, are shown to be macroscale components of the hemispheric general circulation. Major upper level strong anticyclones with associated subsidence develop over the central North Atlantic, North Pacific and Southern Plains with intervening troughs. This amplified circulation pattern, in phase with the normal summer flow pattern, is not only seasonally forced but appears to be reinforced by: 1) interactions with sea surface temperature anomalies, and 2) interactions with dry land through enhanced insolation, high dust counts and radiative effects.

The above conclusions are drawn from analyses of some heat waves of the 1930s, the early 1950s and the most recent 1980 summer when the initial seat of generation was in and over the North Pacific then spreading downstream to a receptive North America and North Atlantic.

A.A.

627. The Natural Environment of Newfoundland, Past and Present. Edited by: A.G. and J.B. Macpherson. Department of Geography, Memorial University of Newfoundland, St. John's. 265 pp. 1981.

The environment of Newfoundland (including Labrador) is the result of complex evolution and has been subject to geographical change through time. Much of the province - its soil, vegetation, wildlife, drainage, climate - has only taken shape during the last 10,000 years, a period nearly coextensive with the presence of humans there. On the other hand, the land surface, adjacent ocean, and bedrock reach back to early stages of the Earth's evolution.

This book consists of eight chapters dealing with the geological evolution, marine and climatic environments, and the plants and animals of Newfoundland. Of these chapters, the most important for this bibliography is J.B. Macpherson's "The Development of the Vegetation of Newfoundland and Climatic Change during the Holocene", which is annotated separately.

C.R.H.

628. NEAVE, K.G., A.S. JUDGE, J.A. HUNTER, and H.A. MACAULAY. 1978. Offshore permafrost distribution in the Beaufort Sea as determined from temperature and seismic observations. Geological Survey of Canada Paper 78-1C:13-18.

Ice-bonded sediments are found over much of the Beaufort Sea continental shelf but are absent from most parts of Mackenzie Bay. They reflect Pleistocene climatic conditions which resulted in the growth of permafrost to depths of 600 m or more. The study made use of oil industry reflection records to determine the distribution of these sediments.

A.A.

629. NELSON, A.R. 1978. Aminostratigraphy of marine and glaciomarine Quaternary sediments, Qivitu Peninsula, northern Cumberland Peninsula, Baffin Island. American Quaternary Association, National Conference, Abstracts 5:226.

Unconsolidated cliff sediments along the outer coast of the Qivitu Peninsula record a series of transgressions and regressions due to isostatic and eustatic sea level fluctuations. All major lithologic units are of marine or glaciomarine origin, suggesting that high relative sea levels coincided with extensive advances of the glaciers in the fiords bordering the peninsula. Amino acid ratios on fossil shells provide stratigraphic control. Although many samples are reworked with fragments of mixed ages, the frequency distribution of free and combined allo/iso ratios can be used to define local "aminozones" which mark periods of high relative sea level when molluscs were relatively abundant. Statistical analysis of lithofacies in 54 stratigraphic sections supports the identification of four marine-glaciomarine-marine cycles in the cliff sediments. A fifth youngest cycle, C^{14} dated at prior to 10,000 BP, lacks a glaciomarine facies suggesting very limited ice extent during the late Foxe Glaciation. Based on subarctic molluscan faunas, the uppermost units in each cycle were deposited by subarctic water masses which extended farther north along the Baffin coast during periods of isostatic depression than today. High *Betula* pollen percentages (20%) in peats overlying subarctic marine deposits suggest the climate may have been warmer than present following the regression of relative sea level at the end of some cycles. Interpretation of allo/iso ratios suggests aminozones corresponding with the two oldest lithologic cycles pre-date the last interglacial.

A.A.

630. NELSON, A.R. 1978. Stratigraphic evidence of ice extent during the last glaciation on Qivitu Peninsula, eastern Baffin Island. Geological Society of America, Abstracts with Programs 10(7):462.

Regional glacio-isostatic movements and fluctuating eustatic sea level during the last glaciation (Foxe Glaciation) have left a series of marine terraces at 15, 25, 40, 70, and 85 masl on the Qivitu Peninsula, northern Cumberland Peninsula, Baffin Island. Moraines and glaciomarine deltas contemporaneous with the higher terraces are found along the fiords on either side of the peninsula, but the relative age of these features cannot be determined using surface weathering and soil profile data. Sediments exposed in coastal cliffs along the peninsula record transgressions and regressions associated with these and earlier changes of relative sea level. All major lithologic units are of marine or glaciomarine origin, suggesting that high relative sea levels coincided with extensive advances of the glaciers in the fiords. Subarctic molluscs in raised marine deposits indicate that subarctic water extended farther north along the Baffin coast during periods of isostatic depression than at present.

Amino acid ratios on shell material in both marine and glaciomarine units provide detailed stratigraphic control and allow correlations with fossiliferous glaciomarine deltas. Although many shell fragments are reworked, the frequency distribution of free and combined allo/iso ratios can be used to define local "aminozones" which mark periods of high relative sea level when molluscs were abundant. Statistical analysis of lithofacies in 54 stratigraphic sections supports the identification of four marine-glaciomarine-marine cycles in the cliff sediments. Estimated maximum rates for isoleucine epimerization, C^{14} and U-series dates, and biostratigraphic evidence suggest the two younger cycles and their corresponding aminozones are of Foxe age. The lack of glaciomarine facies in a younger fifth cycle suggests restricted ice extent during the late Foxe Glaciation.

A.A.

631. NELSON, A.R. 1982. Aminostratigraphy of Quaternary marine and glaciomarine sediments, Qivitu Peninsula, Baffin Island. Canadian Journal of Earth Sciences 19(5):945-961.

A complex sequence of cyclical marine and glaciomarine lithofacies exposed along the coastal lowlands of the Qivitu Peninsula was deposited during the marine transgressions and regressions that affected this area during repeated glaciation of the region. Multivariate analysis of amino acid ratios measured on shell fragments of the pelecypods *Hiatella arctica* and *Mya truncata* in the lithostratigraphic units provides a basis for their chronocorrelation through the use of informal regional aminostratigraphic units termed aminozones. All but the oldest aminozones correspond with particular lithostratigraphic units deposited during transgressive-regressive periods when relative sea level was higher than present sea level. Discriminant analysis shows total amino acid fraction allo/iso ratios from either species are the best overall criteria for assigning a shell sample to a particular aminozone, but free fraction allo/iso ratios are more useful in the younger zones. The distribution of ratios in lithostratigraphic units indicates a large proportion of shell fragments is reworked.

Interpretation of all ^{14}C, uranium-series, paleomagnetic, and amino acid data from eastern Baffin Island suggest aminozone 1 is <11 000 years BP, aminozone 2 is >70 000 years BP, aminozone 3 is >90 000 years BP, and aminozone 4 is >190 000 years BP. The extent of isoleucine epimerization in shell samples indicates some aminozones may be of early or pre-Quaternary age.

A.A.

632. NICHOLS, H. 1967. The post-glacial history of vegetation and climate at Ennadai Lake, Keewatin, and Lynn Lake, Manitoba (Canada). Eiszeitalter und Gegenwart 18:176-197.

Peat from Keewatin and Manitoba contained macrofossil and palynological evidence of former latitudinal movements of the forest-tundra boundary probably in response to the changing location of the mean summer position of the Arctic front. There was very rapid melting of the large late-Wisconsin icesheet between 8000 and 6000 years B.P., and swift immigration of *Picea*, with no evidence of tundra vegetation after deglaciation. From 6000 to 3500 years B.P. the Boreal forest extended far north of its present limit, with a short-lived cooler phase about 5000 years ago. This generally warm period was followed by cooler and variable climatic episodes after 3500 B.P. and by a climatic deterioration about 2600 years ago. There was an amelioration between 1500 and 600 B.P., followed by a prolonged cold episode which terminated peat growth in the tundra. The approximate mean summer temperatures at Ennadai Lake have been estimated from the changing location of the northern limit of forest. The radio-carbon dates for these climatic events coincide with a number of changes recorded in the climatic history of northwest Europe.

A.S.

633. NICHOLS, H. 1967. Central Canadian palynology and its relevance to northwestern Europe in the late Quaternary period. Review of Palaeobotany and Palynology 2(1-4):231-243.

Analyses of fossil pollen grains and macroscopic plant remains have been made of peat from Keewatin and Manitoba in central Canada, at sites in the tundra and at the northern edge of the Boreal forest. Organic accumulation began immediately after very rapid deglaciation of the region between 8,000 and 6,500 years ago, when *Picea* forest swiftly colonized the bare ground. There is no evidence for establishment of tundra vegetation after the ice retreat.

There is evidence from pollen analysis, plant macrofossils and fossil soils that the forest extended north of its present range by about 300 km from 6,000 to 3,500 years B.P. Movements of the forest limit have been interpreted as reflecting climatic change, and in particular the latitudinal movement of the Arctic airmass in summer (which is considered to determine the northern limit of tree growth in central Canada).

Several radiocarbon determinations which have been made of the age of significant horizons in the pollen diagrams show that the inferred climatic changes were synchronous with those experienced by northwestern Europe during the last 6,000 years. The changes in this area also seem to have paralleled those of northern Europe, and this is explained by analogy with the modern pattern of Northern Hemispheric general circulation.

Because of the global nature of circulation patterns it is to be expected that the timing of climatic changes should be the same throughout the world, but not that the change should be in the same direction in all regions. The synchroneity and parallelism mentioned above make it worthwhile to employ palynological evidence from central Canada (relatively undisturbed by human activity) to investigate climatic changes in northern Europe, where the fossil-pollen record for the past 5,000 years has been affected by anthropogenic factors.

A.S.

634. NICHOLS, H. 1967. Pollen diagrams from sub-Arctic central Canada. Science 155(3770):1665-1668.

Peat from Keewatin and Manitoba contained macrofossil and palynological evidence of former latitudinal movements of the forest-tundra boundary in response to the changing location of the mean summer position of the Arctic front. Radiocarbon dating demonstrates the synchroneity of these climatic changes with those registered in northwest Europe during the past 6000 years.

A.A.

635. NICHOLS, H. 1968. Pollen analysis, paleotemperatures, and the summer position of the arctic front in the Post-Glacial history of Keewatin, Canada. American Meteorological Society Bulletin 49(4):387-388.

Work is based on the interpretation of soil stratigraphy, the identification of plant macrofossils, the dating of stratified organic materials by radiocarbon assay, and the analysis of fossil pollen and spores.

"The past changes in the forest limit are believed to have been primarily a response to alterations in summer climate, and in particular to shifts in the mean position of the arctic front in summer, a phenomenon which divides relatively cold dry arctic air to the north (characteristic of the tundra) from warmer moister air of tropical or Pacific origin to the south (associated with the Boreal Forest)."

A tentative reconstruction of the former location of the northern limit of continuous forest along the meridian 100°W in central Canada is presented, and from this is derived estimated changes in mean July temperatures at Ennadai Lake, Keewatin.

L.G.

636. NICHOLS, H. 1968. Palynological contributions to the study of the late-Quaternary climate of northern Canada. Études sur le Quaternaire dans le Monde. Vol. 1, Paris, VII INQUA Congress. pp. 209-215.

The climatic history which has emerged from this study is as follows: a cold period followed 3,400 BP with maximum severity at 2,100 BP or a little before; then a warmer period occurred which culminated about 900 BP, and a subsequent dry, cold phase stopped peat growth in this area.

From 6,800 to 3,200 BP the Boreal spruce forest extended generally north of its present location reflecting a warm, wet climate at the site [Pelly Lake, northern Keewatin, Canada]; from 3,200 to 1,800 BP the forest limit retreated south exposing the site to tundra vegetation as a result of a colder, drier climate.

A.A.+

637. NICHOLS, H. 1969. Chronology of peat growth in Canada. Palaeogeography, Palaeoclimatology, Palaeoecology 6(1):61-65.

Published and unpublished radiocarbon dates from immediately above the unconformable mineral bases of ombrogenous peat bogs are compared with the climatic history of Canada during the last 4,000 years. Most of the determinations group around a few periods of established climatic deterioration (such as 3,500 and 2,400 B.P.) which suggests that large tracts of Canadian peat originated almost simultaneously under the stimulus of climatic change.

A.S.

638. NICHOLS, H. 1969. The late Quaternary history of vegetation and climate at Porcupine Mountain and Clearwater Bog, Manitoba. Arctic and Alpine Research 1(3):155-167.

Radiocarbon-dated pollen diagrams from two sites in the southern Boreal forest of Canada have reflected aspects at the local and regional environments since 6,700 and 1,000 BP, respectively. Spruce forest near Porcupine Mountain was replaced by grassland ca. 6,700 BP, with a maximum of prairie taxa occurring just before 5,140 BP and a short-lived reduction of grass and herb pollen shortly after that date. The grassland episode ended at 4,200 BP when spruce forest dominated Porcupine Mountain. The site experienced very rapid *Sphagnum* peat growth and increased sporogenesis after 2,450 BP.

A tentative climatic interpretation is supplied which suggests that 6,700 to 4,200 BP experienced generally dry, warm summers, with a maximum of this effect just prior to 5,140 BP and a cooler spell following; after 4,200 BP the summer climate was cooler and moister, especially from 2,450 to 2,000 BP. The possibility of a regional increase in soil erosion and sheet flooding prior to 6,700 BP is examined.

Clearwater Bog is underlain by a spruce forest horizon dated 1,200 BP which was established at a time of reduced water level in Clearwater Lake; the *Picea* timbers were overlain by very humified peat dated 900 BP. Unhumified *Sphagnum* peat later formed and continued to the modern bog surface. The climatic interpretation is that the summer climate was warm and dry at 1,200 and 900 BP, and that cooler, wetter summers characterized the period since then to the present day.

The suggested climatic sequences are synchronous at many points with the scheme previously developed for southern Keewatin and northern Manitoba, and some of the vegetational changes are provisionally interpreted as the movement of the southern limit of the Keewatin forest-tundra boundary described earlier. This correlation encourages comparison with other sites in the Northern Hemisphere.

A.A.

639. NICHOLS, H. 1970. Late Quaternary pollen diagrams from the Canadian Arctic barren grounds at Pelly Lake, northern Keewatin, N.W.T. Arctic and Alpine Research 2(1):43-61.

Two peat monoliths were recovered from the high arctic tundra, now too dry and cold to permit peat growth, near Pelly Lake (66°N, 101°W). The organic materials began to accumulate at 3,400 and 1,100 BP respectively, and both ceased shortly after 900 BP. Absolute pollen counts, based on numbers of pollen grains per gram (oven-dry weight), revealed parallel changes in representation of *Pinus* and *Picea* pollen which were windblown into the tundra from the Boreal conifer forest 400 to 500 km to the south and west. The absolute numbers of pine and spruce pollen declined after 3,360 ± 70 BP to joint minima at about 2,080 ± 60 BP, then rose and culminated in joint maxima at 900 ± 75 BP, and then decreased. These variations in *Pinus* and *Picea* counts were probably due to the previously established quasi-latitudinal movements of the forest-tundra ecotone described from Ennadai Lake (500 km south), with which they were synchronous and parallel. The local tundra taxa provided little palynological evidence of climatic changes.

The suggested climatic history is that a period of cold summers followed 3,400 BP, with an episode of maximum severity at ca. 2,100 BP, then a period of warmer summers occurred which culminated about 900 BP, and a subsequent cold dry phase, which extended to the present, stopped peat growth in this area. The *Pinus* and *Picea* maxima coincided with the shortlived growth of a local peat bank from 1,060 ± 55 to 940 ± 60 BP which was synchronous with the Scandinavian exploration and colonization of the North Atlantic.

A.A.

640. NICHOLS, H. 1972. Summary of the palynological evidence for late-Quaternary vegetation and climatic change in the central and eastern Canadian Arctic. Climatic Changes in Arctic Areas During the Last Ten-Thousand Years. Edited by: Y. Vasari, H. Hyvärinen and S. Hicks. Acta Universitatis Ouluensis Series A, Scientiae Rerum Naturalium 3, Geologica 1:309-338.

The author has inferred climatic conditions based on Holocene palynological records from several sites in the Canadian Arctic: Colville Lake, MacAlpine Lake, Pelly Lake, Ennadai Lake, Axel Heiberg Island, Sugluk and Bathurst Inlet. These sequences show many similarities in the timing and direction of climatic change despite variations in climatic sensitivity. Evidently large sections of the forest-tundra ecotones underwent synchronous, quasi-latitudinal shifts in response to late Quaternary climatic changes.

C.R.H.

641. NICHOLS, H. 1974. Arctic North American paleoecology: the recent history of vegetation and climate deduced from pollen analysis. In: Arctic and Alpine Environments. Edited by: J.D. Ives and R.G. Barry. Methuen, London. pp. 637-667.

Pre-6000 BP: Relatively warm climates (warmer than present) are indicated by spruce forest northern range extensions, rapid peat growth at Colville Lake, and extremely quick melting of the Late Wisconsin ice sheet in the Ennadai Lake area.

6000-5000 BP: A warmer climate continued throughout this period. The northward extension in Quebec of white pine by almost 100 km implied a wetter, cooler peat-forming episode followed 5000 BP.

5000-3500 BP: A climatic cooling in the Canadian Arctic is suggested by glacial advances and evidence of treeline lowering. A recovery to a warmer climate occurred some centuries later, beginning at Ennadai Lake at c 4500 BP and continuing to 3500 BP, with estimated summer temperatures c 3°C above modern values.

3500 or 3300-2000 BP: Arctic climates cooled, in a regular decline, until c 2500 or c 2200 BP. An episode of severely cold climate, maximum severity c 2100 BP, saw the widespread southern extension of tundra.

2000 BP - Present: By 2000 BP recovery from the severe climatic cooling had begun. Summer temperatures at Ennadai Lake were estimated to be c 1.5°C above present; a maximum of summer warmth occurred c 1000 BP at Pelly Lake. Colder summers followed 900 BP. A widespread cessation of peat growth at Pelly Lake (900 BP), Ennadai (630 BP) and Sugluk (670 BP) was the result of colder, drier summers. Peat growth has not resumed at any site.

The author believes it is possible to argue that the Late Quaternary climatic histories of the Alaskan and Canadian arctic sites summarized here exhibit a common timing and direction of climatic change comparable to those seen in Greenland and northern Europe and northern Russia.

A.B.S.

642. NICHOLS, H. 1975. Holocene tree-line fluctuations and climatic changes in Mackenzie and Keewatin territories[1], Canada. Quaternary Non-marine Paleoecology Conference, University of Waterloo, Waterloo. Program and Abstracts.

Eight pollen diagrams were obtained from five sites in subarctic Canada near modern tree-line, along an east-west ecotonal line 1300 km long. "Absolute" pollen analyses, peat stratigraphy and wood macrofossils clarify previous evidence of climatically-induced subarctic tree-line movements during mid- to late-Holocene times.

The major climatic events registered at all the sites were synchronous and parallel, though continental interior forest movements were greater than in northwest Canada. Summers were substantially warmer than now from 6800 to 3000 BP, with tree-growth up to 400 km north of modern forest, resulting from mean summer temperatures 4°C higher than now. At 5000 BP there was minor warming, followed by summer cooling at 4800-4400 BP. Warming followed and peaked about 3900 BP, and then fires affected the forest until about 3000 BP. A major fire episode was universally recorded at 3600-3500 BP, resulting from climatic change. Prolonged colder summers after 3000 BP forced forest retreat and tundra expansion, with further cooling at 2500 BP. Maximum cooling occurred at 2200-2100 BP. There was some summer temperature recovery by 1900 BP, more strongly marked by 1500 BP. Some warming around 1100 BP was followed by very cold dry summers from 700 BP to present.

Revised versions of published Holocene tree-line movements and extrapolated summer paleo-temperature reconstructions are presented.

A.A.

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[1] Ed. note: In fact, these are Districts of the Northwest Territories.

643. NICHOLS, H. 1975. Palynological and paleoclimatic study of the late Quaternary displacements of the boreal forest-tundra ecotone in Keewatin and Mackenzie, N.W.T., Canada. Arctic and Alpine Research Occasional Paper 15:1-87.

A series of six pollen diagrams was prepared from peat profiles from four sites along the Canadian boreal forest-trundra ecotone to detect ecotonal displacements due to climatic changes. Two additional short profiles from the High Arctic tundra were prepared to examine the sensitivity of such analyses to influx of exotic forest pollen due to paleowind shifts and forest displacements. Bryson's (1966) hypothesis of the control of the northern forest by the mean summer position of the Arctic Front was used throughout.

The broad outline of the climatic changes is as follows:

The oldest sediments dated back to 6200 BP in an area deglaciated about 8000 BP (Bryson et al., 1969) and represented a spruce forest environment substantially warmer in summer than now. This hypsithermal warmth continued until 4800 BP, with possible evidence of cooling at 5600 to 5500 BP and a maximum of summer warmth from 5300/5200 BP to 4800 BP.

A cold summer episode from 4800 BP for several centuries expanded tundra almost down to its modern limit, and recovery took place between 4500 and 4250 BP, depending on lag in plant colonization. At 4200 BP there was a brief cooling followed by a peak of summer warmth around 4000 to 3900 BP. From about 4000 to 3000 BP there were frequent forest fires throughout the northern forest. The forest was able to recover from these until 3500 BP when widespread and broadly synchronous fires swept the ecotone from one end to the other over a period of 100 or 200 years. This was due to summer expansion of cold dry arctic air masses over the northern forest, which then changed to tundra until 3300 BP. By 3200 BP some woodland regeneration registered milder summers, but by 3000 BP tundra expanded southwards in a prolonged episode of colder summers. Further cooling at 2500 BP forced another southward ecotonal retreat and damaged the tundra plant cover so that windblown sand was incorporated in peat. Maximum cooling occurred at 2200 to 2100 BP. When warming followed, vegetational recovery was registered at several dates between 2000 and 1500 BP, due probably to plant migrational lag. Brief cooling occurred at 1400 BP. Warming around 1200 to 1000 BP allowed a minor woodland advance, followed by a major cooling after 800 to 600 BP which caused a major forest retreat. Many peat profiles ceased growth and have not regenerated since. Some minor warming may have been registered within the last 150 years at a minority of sites.

A survey of eight ecotonal pollen diagrams spanning 1400 km east-west from the west short of Hudson Bay to beyond Great Bear Lake demonstrates clear synchrony and parallelism in the movement of this boundary in response to climatic changes over at least the last 6000 ^{14}C years. There is some preliminary evidence which may indicate a greater amplitude of Holocene ecotonal displacement in the continental interior of Keewatin and Mackenzie than in northwest Canada, possibly 400 km as compared to about 250 km. This was presumably due in the northwest to the diminished movement in the upper atmospheric ridge due to compression between the Cordillera and cold Arctic Ocean. This may imply that the Canadian northwest was less sensitive to paleoenvironmental change than the continental interior.

An apparently normal aspect of the stability of this forest ecosystem was the instability of fairly frequent major fires at intervals of one to two centuries, from which the forest recovered usually within fifty years during the long episodes of favourable climate. It is tentatively deduced from the pollen diagrams that sizable areas of open woodland (e.g., north of Great Bear Lake) may be out of equilibrium with the modern climate and may be overdue for a major fire, after which the trees might be replaced by shrub-tundra.

A schematic reconstruction is presented of the changes in ecotonal location and the deduced summer paleotemperatures, which broadly supports earlier tentative findings (Nichols, 1967a, 1967b).

pA.S.

644. NICHOLS, H. 1976. Climatic variability and recent cooling in northern Canada during the present interglacial. Geological Society of America, Abstracts with Programs 8(6):1028.

Analogs for climatic changes at the end of the last interglacial may be sought in climatic interpretations of the Holocene vegetational history of northern Canada, in regions where the last glaciation began. Maximum sensitivity to Holocene climatic changes was found at the forest-tundra boundary, controlled by the summer limit of the arctic airmass. Summer paleotemperature schemes derived from the ecotonal displacements include numerous climatic alterations, with many sharp, short outbreaks of arctic air, even interrupting the hypsithermal warmth by mean summer temperature reductions of 3°C; these coolings were apparently step-like, and progressively pushed the tree-line south in the last 3500 years. Parallel changes affected a few sites at the southern forest edge at the same time, implying wholesale southward displacement of the Boreal forest southwards in the late Holocene. Equivalent ecotonal shifts should be detectable in late Sangamon sediments, and should provide a perspective on the parallels between the hypothermal episodes of the two interglacials. Long-distance transport of windblown pollen as a direct response to Holocene meteorological changes is being used to test these schemes derived from tree-line shifts, and this approach may be applicable to Sangamon sediments.

A.A.

645. NICHOLS, H. 1976. In or out of phase Holocene climatic changes in the Canadian Arctic based on palynology. American Quaternary Association, Abstracts 4:113.

The modern relationship between the Canadian forest-tundra boundary and summer climatic parameters makes the history of this ecotone a useful indicator of past climatic status over much of northern North America. Palynological studies of Holocene tree line displacements between west Hudson Bay and Great Bear Lake demonstrate synchronous and climatically uniform behaviour (Nichols, 1975), while data from east Hudson Bay and Mackenzie Delta have been previously interpreted out of phase or in antiphase. Reinterpretations of these latter data now show uniform tree line responses across a very large area of the north. There are more than two dozen pollen diagrams by several workers spanning 5000 km east-west which form a framework for regional paleoclimate. This evidence comes from palynological, macrofossil and stratigraphic studies of tree line displacement, and of long-distance windblown tree pollen in tundra sediments, and is supported by parallel evidence from fossil soil studies (Sorenson and Knox, 1973). This large body of data can be linked by a common climatic theme, with local variations due to local plant succession, soil development, etc., but climatic change is clearly the underlying forcing function.

The climatic scheme is summarized: 6500 BP - 4800 BP warmer summers than modern, maximum warmth 5300 - 4800; 4800 - 4600 cold; 4600 - 3600 warm; 3600 - 3000 cold, then warm; 3000 - 2000 cold, especially 2500 - 2100; 2000 - 800 minor warming; 800 - 0 BP cold, with recent warming. This is similar to that proposed for northern New England (Bradstreet and Davis, 1975). All northern Canadian pollen diagrams seem to fall into this broad pattern except for a few insensitive sites: exceptions are solicited.

A.A.

646. NICHOLS, H. 1976. Historical aspects of the northern Canadian tree line. Arctic 29(1):38-47.

From palynological studies it appears that northernmost dwarf spruces of the tundra and part of the forest-tundra boundary may be relics from times of prior warmth, and if felled might not regenerate. This disequilibrium may help explain the partial incongruence of modern climatic limits with the present forest edge. Seedlings established as a result of recent warming should therefore be found within the northernmost woodlands rather than in the southern tundra.

A.A.

647. NICHOLS, H. 1978. The INSTAAR Program of paleo-environmental research in the eastern Canadian Arctic. American Quaternary Association, National Conference, Abstracts 5:227-229.

This study involves a team effort to collect, analyze and interpret paleo-environmental data from two regions of north-eastern Canada which apparently formed "trigger areas" for past glacial inception (Labrador-Ungava and Baffin Island), and may be implicated in future glaciations. These areas are being used to test the wider applicability of the Holocene paleo-climatic scheme previously derived from arctic tree-line movements throughout the Northwest Territories west of Hudson Bay.

(The various studies and their methodologies are reviewed.)

Fossil pollen diagrams have been prepared from lake sediments from the northern Labrador woodlands (Short and Nichols, 1977) reaching back to 9-10,000 BP, and further diagrams are in preparation, selected from a score of available lake and peat cores. Initial interpretations of "absolute" counts suggest mid-and-late Holocene sequences of climatic history similar to those we reported west of Hudson Bay, but with tundra episodes in earlier Holocene time which contrast with the forested periods in north-west Canada. The simple equation of tundra vegetation with cold climate may however, in this case, obscure the possibility that the climate was sufficiently warm to support woodland, but that the arrival of trees was greatly delayed in migrational response to early Holocene warmth; substantial long-distance influx of tree pollen during the tundra episode (probably due to warm southerly winds) supports this notion (Short and Nichols, 1977, and P. Mudie, p.c.). The early Holocene vegetational contrasts between eastern and western sub-arctic Canada may thus be more apparent than real in their climatic implications.

Trace amounts of wind-blown exotic tree pollen in high-arctic tundra sediments of Baffin Island have proved useful in deducing precise paleo-wind directions based on pollen ratios; the warmest episodes were associated with forest pollen carried into eastern Baffin Island by due south winds (Nichols, Kelly and Andrews, 1978).

Modern pollen production, seed viability, and tree regeneration at tree-line are being examined in comparative studies in Keewatin and Labrador-Ungava by D.L. Elliott, to aid comprehension of tree pollen influx into the tundra. Initial data support the hypothesis (derived from historical palynology) that isolated stands of trees in the tundra and the northern-most woodland fringes resulted from previous warmer episodes and are not in equilibrium with modern climate.

pA.A.

648. NICHOLS, H., P.M. KELLY, and J.T. ANDREWS. 1978. Holocene palaeo-wind evidence from palynology in Baffin Island. Nature 273(5658):140-142.

The authors report that "traces of exotic pollen in late Holocene sediments from Baffin Island can be used as palaeo-wind indicators, and may be associated with periodic shifts of a trough in the atmosphere". The pollen grains examined are from peats from Cumberland Peninsula, a region affected by changes in trough positions, where it is possible to determine quite precisely the source, and thus the direction, of growing-season paleo-wind. There is a possibility of periodicity in these southerly paleo-winds.

L.G.

649. NIELSON, E. 1974. A mid-Wisconsinan glacio-marine deposit from Nova Scotia. In: Quaternary Environments: Proceedings of a Symposium. Edited by: W.C. Mahaney. First York University Symposium on Quaternary Research. Geographical Monographs No. 5:59-60.

The presence of the extinct gastropod *Atractodon stonei* (Pilsbry) in the marine deposit at Salmon River, Nova Scotia convinced earlier workers that the deposit should be assigned to the Sangamon Interglacial in spite of two finite C^{14} dates averaging 38,600 ± 1,300 yr BP. No reason can be found for believing that the C^{14} dates are erroneous; nor is it clear why *Atractodon stonei* (Pilsbry) is considered to have become extinct during the Sangamon. However the two conclusions are incompatible.

The sections comprise a lower till, designated A, overlain by gray fossiliferous sand and oxidized brown fossiliferous sand - collectively named the Salmon River beds - and three overlying tills B,C, and D. Ice rafted granules, pebbles, cobbles and boulders are common throughout the Salmon River beds.

Studies of fabric and the presence of thin, well sorted, horizontally deposited sand layers in the bottom meter or so of till B suggest that part of till B was deposited in a proglacial lake and marine embayment. The upper part of till B and all of till C and D were deposited on land.

The Salmon River beds and till B represent a continuous depositional sequence from glacio-marine, to water deposited till, to terrestrial till. This sedimentary sequence was apparently produced by a calving ice shelf supplying ice-rafted material to a sandy, shallow marine environment followed by advance of ice into the sea with sea level lowering (probably eustatic). Fauna from the marine beds indicate water temperatures warmer than around Nova Scotia today. If the northern edge of the Gulf Stream was closer to Nova Scotia when the Salmon River beds were deposited it would have been possible for a warm-water fauna to live close to a calving ice shelf.

The top of the Salmon River beds is at approximately +6 m and the faunal evidence suggests deposition in approximately 10 m of water. If their age is Mid-Wisconsinan, and sea level was at -25 m , the total post-Salmon River bed rise of the land must have been approximately 41 m. The glacier advance that deposited till A prior to 38,600 yr BP is inferred to have been extensive enough to cause at least this amount of glacio-isostatic down-warping before deposition of the Salmon River beds.

The study establishes: (1) Nova Scotia as being ice free for part of the Mid-Wisconsinan, (2) a possible mechanism for creating a unique glacio-marine environment at the ice margin in south-western Nova Scotia for part of the Mid-Wisconsinan, and (3) an important marker in the Nova Scotian till stratigraphy.

A.A.

650. NUTT, D.C. 1959. Recent study of gases in glacier ice. Polar Notes 1:57-65.

The author reviews several studies investigating gases in glacier ice. These studies have been predominantly from Greenland and Antarctica. He concludes that "by application of the new techniques now available the study of gas inclusions in glacier ice can provide useful information about past atmospheric composition and climatic conditions as well as for the interpretation of glaciological and related phenomena."

A.B.S.

651. OCCHIETTI, S. 1978. Lithology, stratigraphy, paleogeography and chronology of the St. Narcisse morainic system. Geological Society of America, Abstracts with Programs 10(7):465.

The St. Narcisse morainic system, approximately 550 km long, indicates an irregular pattern of retreat at the margin of the Laurentide ice-sheet. It varies from a short readvance in the easternmost part to accumulations of outwash and ice-contact deposits at the westernmost one. The setting of the moraine, inland on the Mt. Tremblant and the Parc des Laurentides Highlands, suggest strongly a topographically controlled ice margin. About 30% of the known length of the moraine was built in contact with the Champlain and Goldthwait seas. It has not been demonstrated that the different segments are of the same age. The moderate width of the morainic ridges implies a relatively short period of reactivation of the ice. The average age is estimated to be 10,800 ± 200 BP, taking into account: (1) the contradictory ^{14}C ages of marine shells and organic matter; (2) the chronological scale derived from the regional deglaciation patterns and (3) the rates of isostatic rebound. The St. Narcisse morainic system is tentatively correlated with Sands Sturgeon, Brador and Ten Mile Lake moraines. It has some common characteristics with the Scandinavian moraines of the Dryas III time. Apparently, the system is the result of a large scale response of the southern margin of the Laurentide ice-sheet to (1) the world wide cooling of Dryas III and (2) a reequilibration of the ice profile after strong wastage of the ice into the postglacial seas.

A.A.

652. **OCCHIETTI, S., and C. HILLAIRE-MARCEL. 1977. Chronologie ^{14}C des événements paléogéographiques du Québec depuis 14 000 ans. Géographie physique et Quaternaire 31(1-2):123-133.**

A distribution curve of dates on post-glacial marine shells in Eastern Canada was compiled taking into account laboratory error. Most of the variations identified on this curve may be qualitative indicators of secondary climatic fluctuations. Positive values would be related to climatic warming and to rises of mean sea level greater than or equal to isostatic rebound; negative values would indicate a relative lowering of shorelines in relation to the uplifting land and also represent different steps in the deglaciation. Fluctuations in the curve are correlated with paleogeographic events already identified in Quebec and elsewhere. The curve therefore provides a chronological frame of reference, with its limits. The curve shows some major disparities in relation to calendar years. Each date is subject to the limits of the ^{14}C method and to variables modifying initial ^{14}C composition of marine organisms. Therefore the proposed time scale of the chronological frame of reference is divided up into "^{14}C cold water marine shell" years. Statistical validity is assured because of the large number of uniformly analyzed radiocarbon dates. Paleogeographic relevance can be seen from the persistence of the same modes from one postglacial sea to the other and by good chronological correlations with the events of the Great Lakes area.

A.A.

653. **OGDEN, J.G., III. 1960. Recurrence surfaces and pollen stratigraphy of a postglacial raised bog, Kings County, Nova Scotia. American Journal of Science 258(5):341-353.**

Pollen analysis of a core from a postglacial raised bog at the head of the Annapolis River Valley, Kings County, Nova Scotia has revealed the presence of five periods of peat growth. These periods of peat growth are recognized by the occurrence of light-colored waxy *Sphagnum* peat overlying a dark-colored humified *Sphagnum* peat. The stratigraphy and microfossil content of the light- and dark-colored peat layers are closely similar to those of European raised bogs. Recurrence surfaces in Europe have been dated by pollen stratigraphy, archeology, and by radiocarbon methods. Many recurrence surfaces have been found to be approximately the same age over wide areas. Periods of peat growth (as shown by the development of lighter-colored less humified peats) have been shown to correspond with periods of increased atmospheric moisture.

Testaceous rhizopods in the light-colored peat layers of Caribou Bog confirm the similarity of the recurrence surfaces of this bog with those of western Europe and Scandinavia. Chronologic equivalence of the Caribou recurrence surfaces with those of western Europe and Scandinavia can not be established from this study.

Alkali-extracts of the peat (see Overbeck, 1952) have been used to characterize the sediment color differences above and below the recurrence surface horizons. A simpler technique, based on sieved fractions of the sediment is satisfactory and less time-consuming for describing differences in sediment color density.

The pollen stratigraphy of core CAR-1 resembles the pollen sequence described by Auer (1930) from the same bog. Correlation of the Caribou Bog sequence with data from Gillis Lake on Cape Breton Island (Livingstone & Livingstone, 1958) and from Aroostook County, Maine (Deevey, 1951) is also discussed. There is no evidence for any major climatic reversal. The pollen data indicate a gradually warming climate with minor oscillations of moisture (and perhaps temperature).

A.A.

654. **OGDEN, J.G., III. 1965. Pleistocene pollen records from eastern North America. Botanical Review 31(3):481-504.**

A review article on available pollen records from pre-and early Wisconsin to modern times. Studies at Gillis Lake, Nova Scotia, the Missinaibi beds, James Bay, the Don beds, Toronto and the Port Talbot Interstadial beds are included, together with inferred climatic conditions. Plant macrofossils are also discussed. Problems in paleobotany are outlined.

L.G.

655. **OGDEN, J.G., III. 1977. The late Quaternary paleoenvironmental record of northeastern North America. In: Amerinds and Their Paleoenvironments in Northeastern North America. Edited by: W.S. Newman and B. Salwen. Annals of the New York Academy of Science 288:16-34.**

The author reviews current understanding of late-and postglacial environments in northeastern North America since the retreat of late Wisconsinan ice and examines some characteristics of the available data. He reconstructs the environmental history of the sector and points out gaps in information. "Although ice retreat began 16,000 B.P. the period from 14,000 to 12,000 B.P. saw the greatest amount of land in the "northeastern corridor" opened up and anticipated the evident major climatic change recorded about 11,300 B.P. The establishment of the deciduous forest in the northeast occurred very rapidly in the period from 11,000 to about 9,000 B.P. and represents an environmental and presumably climatic event more dramatic than any that have occurred before or since. Minor but consistent changes in the proportion of hemlock, beech, hickory, and elm pollen throughout northeastern North America reflect subtle but important differences in effective moisture and temperature."

L.G.

656. **OGDEN, J.G., III. 1980. Late Quaternary paleoenvironments of eastern Canada. In: Climatic Change in Canada. Edited by: C.R. Harington. Syllogeus 26:225-246.**

The author reviews the development of three principal tools developed during the past three decades; radiocarbon dating, digital computers, and multivariate statistics. These techniques have led to more sophisticated paleoenvironmental reconstructions. He then outlines the "preliminary results of an attempt to collate paleoecological information from eastern Canada". This includes "Age-depth regression of selected radiocarbon-dated sediment sequences in eastern Canada" and a "Preliminary list of radiocarbon dates on sediment cores from eastern Canada".

A.B.S.

657. **OGDEN, J.G., III. 1981. There's a chill in the air. In: Climatic Change in Canada 2. Edited by: C.R. Harington. Syllogeus 33:10-18.**

The author provides a brief review of Nova Scotia's climate. He then discusses the historical records available for analysis. His graphics illustrate an increase in heating degree-days (computed from the number of days times the number of degrees the temperature is below 18.3°C, and frequently used in predicting the demand for heating fuel) and a decrease in growing degree-days (number of days above 5.6°C representing the amount of heat required for the initiation of plant growth). Both these trends have serious economic implications.

A.B.S.

658. O'NEILL, B.J. 1981. Pliocene and Pleistocene benthic foraminifera from the central Arctic Ocean. Journal of Paleontology 55(6):1141-1170.

A study of Pliocene and Pleistocene benthic foraminifera in eleven piston cores from the central Arctic Ocean was undertaken to examine the development of the fauna and to make inferences about Arctic paleoceanography during the late Cenozoic. The foraminifera can be divided into three biofacies based on the changing faunal patterns. The Textulariid Biofacies, which is the oldest, existed during the early Pliocene and was dominated by textulariids (20 species). Nineteen rotaliid and three miliolid species are also present in this biofacies, but all are extremely rare. The Transitional Biofacies existed from the end of the early Pliocene to the middle of the early Pleistocene. During this time calcareous forms became more abundant and three rotaliid and two miliolid species appeared. Textulariid diversity dwindled during this time. The Rotaliid Biofacies has existed in the central Arctic since the mid-early Pleistocene and a trend toward increased rotaliid diversity and abundance has continued to the present. Twenty-six rotaliid and two miliolid species appeared during this time.

The sequence of biofacies is interpreted as indicating moderation of bottom conditions in the central Arctic through late Cenozoic time. The cause of this moderation is suggested to be increased Atlantic influence on the Arctic due to widening and deepening of the Greenland-Spitzbergen passage and a thinning of the Arctic ice-cover during the early Pleistocene.

Seventy-five species of foraminifera including two new textulariids, *Haplophragmoides obscurus* n. sp. and *Alveolophragmium polarensis* n. sp., were recognized in the cores studied.

A.A.

659. ORVIG, S. 1959. Ice caps and climate. In: Problems of the Pleistocene Epoch and Arctic Area. Compiled by: G.R. Lowther. Publications of McGill University Museums, (Montreal) No. 1. pp. 46-54.

The author reviews the known history of climate during the Pleistocene and some of the attempts to explain climatic fluctuations during that period. He points out that long-term climatic changes are probably due to a combination of factors. He discusses the question of influence of ice and snow cover on atmospheric circulation and periglacial climate, concluding that "The ice masses in the eastern Canadian Arctic are all of little or no importance to the present climate. Northern Baffin Island and Ellesmere Island have glaciers showing no marked recession in the last few decades, and the ice-caps seem to be in a state of approximate balance. Only small fluctuations in temperature and precipitation conditions will cause these ice masses to expand or waste away. The same is probably the case with all ice in the northern hemisphere, with the exception of the inland ice of Greenland. Only this topographical barrier and vast source of cooling is capable of influencing the circulation of the Arctic. It is highly probable that Brooks' critical size for an ice sheet (30,000 square miles) is relatively accurate. Smaller icecaps will not have important effects on temperature or precipitation conditions."

L.G.

660. OSTERMAN, L.E. 1978. Preliminary results of a study of cores from outer Frobisher Bay. American Quaternary Association, National Conference, Abstracts 5:230.

Three piston and four trigger weight cores from Frobisher Bay, Baffin Island, have been sampled to determine the glacial history of the region. Analyses of foraminifera, sediment size and pollen are in progress. Field work is also being done in Frobisher Bay which will be correlated to the marine record.

The stratigraphy of the outer cores, HU77-156 and HU77-157, shows a green coarse-grained diamicton on top of fine-grained grey laminated silty muds. The inner cores, HU77-159 and HU77-160, do not have a noticeable diamicton layer and are composed of green-black silty muds with scattered layers of coarser sediment.

Two C^{14} dates on shells and sediment have provided estimates of the sedimentation rates in the bay. Core HU77-159, 969 cm long, has a date of 14,435 ± 450 BP at 496 cm, and a calculated sedimentation rate of 34 cm per 1000 years. Core HU77-157, 142 cm long, has a date of 24,500 (+1825, -1485) BP at 42 cm, and a sedimentation rate of 1.7 cm per 1000 years. Using this sedimentation rate for HU77-157, the green diamicton at the top of the core represents sedimentation over the last 5,100 years, and may suggest a return to colder conditions and greater ice rafting.

Given the lengths and the sedimentation rates of these cores, they should provide a record of climatic fluctuations, interpreted from foraminifera, sediment size and pollen, over the last 30,000 years for HU77-159, and 88,000 years for HU77-157.

A.A.

661. OSTREM, G. 1966. The height of the glaciation limit in southern British Columbia and Alberta. Geografiska Annaler 48A(3):126-138.

A number of methods for determining the climatic snowline are briefly described. The firn line on glaciers will normally lie slightly lower than the climatic snowline; however, most previous methods for its determination are connected with observations on glaciers. From a study of the distribution of glaciers and the altitudes of surrounding mountain summits, it is possible to determine a critical height (the "glaciation limit") which has normally to be exceeded if glaciers should form. This height is approximately 100 metres above the climatic snowline.

The glaciation limit was determined on a large number of topographic maps, the results plotted on a small-scale map, and contour lines were drawn showing its regional variation in southern British Columbia and Alberta. The source material and possible errors in the determinations are discussed. A comparison is made with different maps showing precipitation, continentality, land surface elevation, and the 1961 firn line altitude of glaciers. It is concluded that the height of the glaciation limit is inversely connected with the precipitation distribution.

A.A.

662. OSTREM, G. 1972. Height of the glaciation level in northern British Columbia and southeastern Alaska. Geografiska Annaler 54A(2):76-84.

In glacierized areas there exists a critical height under which glaciers do not normally develop. Above this height glaciers will form on mountains with a favourable topography (e.g., not too steep slopes). It is of glaciological interest to determine this critical height because it has relevance to certain climatological elements, e.g., continentality.

A previously developed method, the so-called "summit method" was used in this study to determine the critical height which it is necessary for mountains to exceed - within a given area - to obtain a glacier. This critical height is termed "glaciation level". Studies of topographic maps, in general covering a unit area of 15x27 km (one "half-sheet" 1:50,000 map), revealed the summit elevations of the highest glacier-free and lowest glacier-carrying mountains. The height of the glaciation level was calculated as the arithmetic mean of these two summit elevations. To check the quality of source maps, a comparative study was performed in areas where maps of various scales were available. In general, a somewhat higher glaciation level was found when the 1:250,000 maps were used. This is thought to be a result of generalization and omittance of small glaciers on these maps.

Resulting heights, valid for each single unit of area, were plotted on a glacier map at a scale of 1:2,000,000 and 100-m contours were drawn. The resulting map indicated that the height of the glaciation level increases from about 900 or 1000 m at the coast to a maximum of 2700 m in the Rocky Mountains. However, there are certain exceptions from this general rule - local maxima and certain depressions occur.

Depressions in the height of the glaciation level are thought to be related to large-scale topographic openings in the Coast Mountain system, allowing maritime air masses to penetrate further inland in certain areas. Detailed winter precipitation studies in the Kitimat-Terrace area support this assumption. Comparisons were also made with a map of continentality for Canada that indicated a similar depression in the same area. Snowline investigations in Scandinavia have also shown local depressions in transient snow line altitude in areas of maritime influence.

A.A.

663. OUELLET, M.H. 1975. Paleoclimatological implications of a Late Quaternary molluscan fauna from Atkins Lake, Ontario. International Association of Theoretical and Applied Limnology Proceedings 19:2251-2258.

Freshwater molluscs appear to be poor indicators of paleoclimatic fluctuations as revealed by pollen analysis because of their wide environmental tolerance. Their abundance in Quaternary lacustrine deposits is probably largely controlled by factors internal to the aquatic ecosystem such as water and sediment physicochemistry, predation and aquatic vegetation.

A better understanding of these factors and their interrelationship with the aquatic molluscan fauna might provide us in the future with a more accurate paleolimnological tool which is greatly needed to shed light on the ontogeny of our lakes.

A.C.

664. OUELLET, M., et R. POULIN. 1976. Etudes paléoécologique des sédiments du lac Waterloo, Québec. INRS-Eau (pour le Ministère des Richesses naturalles, Québec), rapport scientifique 64:1-87.

Studies of pollen, algae and geochemical samples from sediment cores from the bottom of Lake Waterloo (Shefford County, Quebec) led to the conclusion that the invasion of the region by forest about 11,500 years B.P. (evidently shrub-birch grassland dominated for the preceding 1,000, or more, years) had a significant effect on the ecological conditions of the lake. During the forest period, which lasted about 10,000 years, climatic changes and soil development within the drainage basin were the main factors controlling the development of Lake Waterloo.

Most of the climatic data are summarized in Figure 7 (Chronology of the paleoecological history of Lake Waterloo): from about 12,700 to 11,500 years B.P. - very cold; from about 11,500 to 10,500 years B.P. - cold; from about 10,500 to 8,500 years B.P. - less cold; from about 8,500 to 5,500 years B.P. - warmer and dry; from about 5,500 to 4,500 years B.P. - warmer?; from about 4,500 to 3,000 years B.P. - warm and humid; from about 3,000 years B.P. to present - colder and humid.

C.R.H.

665. PACKER, J.G. 1980. Paleoecology of the ice-free corridor: the phytogeographical evidence. Canadian Journal of Anthropology 1(1):33-35.

Extant floras are repositories of information about their past history (Packer, 1971), and it might be thought a fairly simple matter to ascertain how a particular flora came into existence and what factors were of major importance in shaping it. However, this is certainly not the case and many problems are associated with trying to understand the evolutionary development of any existing flora, notwithstanding the fact that it is now possible to obtain virtually unlimited information on such critical factors as the physical environment, physiological tolerances and responses of plants, population dynamics, breeding systems, cytology, etc. Unfortunately, even with this potential, the analysis of factors responsible for a particular species distribution present insoluable difficulties, and why a species that has one distribution and not another can seldom, if ever, be answered.

At the present time phytogeographic studies in the area of the ice-free corridor have been quite limited. One hopes the current paleoecological progress in the area will be paralleled by an increasing knowledge of its modern flora and phytogeography. If it is, when the eventual synthesis of corridor paleoecology is attempted, studies of the extant flora will form part of the framework into which the more localized biostratigraphical data are fitted.

Excerpts

666. PARKER, M.L. 1976. Improving tree-ring dating in northern Canada by X-ray densitometry. Syesis 9:163-172.

The potential for obtaining dates from tree-ring samples and of using tree-ring series for climatic studies is improved through the use of X-ray densitometry. Tree-ring samples from two locations in the Northwest Territories, near Inuvik in the Mackenzie Delta and on Nahanni Butte in the Fort Simpson area, are analysed. The intra-annual ring components of earlywood and latewood for both ring width and ring density are compared with one another and with climatic factors. Latewood density values provide the best series for crossdating tree-ring samples. Tree-ring variables are more closely related to temperature than to precipitation, and density parameters generally relate more closely to climate than do width variables. Ring-width response to temperature occurs later in the year in the Mackenzie Delta than in the Fort Simpson area.

A.A.

667. PARKER, M.L., and W.E.S. HENOCH. 1971. The use of Engelmann spruce latewood density for dendrochronological purposes. Canadian Journal of Forest Research 1(2):90-98.

Two parameters of growth rings from Engelmann spruce (*Picea engelmannii* Parry) near Peyto Lake, Alberta were studied and compared. Indices of maximum density of the latewood were derived from densitometric plots of X-ray negatives. Indices of ring widths were also obtained from the same specimens. Latewood density proved to be more useful for dendrochronological studies than ring width. The indices of density were significantly correlated with mean maximum air temperature and monthly runoff during August for three rivers in the region near Peyto Lake. Analysis of latewood density as well as ring width improves the potential for dating ring-tree materials, and for using them to estimate past environment, especially for trees, such as the Peyto Lake Engelmann spruce, with rings that do not vary greatly in width from one year to the next.

A.A.

668. PARKER, M.L., L.A. JOZSA, S.G. JOHNSON, and P.A. BRAMHALL. 1981. Dendrochronological studies on the coasts of James Bay and Hudson Bay (Parts 1 and 2). In: Climatic Change in Canada 2. Edited by C.R. Harington. Syllogeus 33:129-188.

Tree-ring samples were collected from four major sites in Quebec along the coasts of James Bay and Hudson Bay in June, 1979. The tree-ring proxy data are required for checking and verifying historical records that were kept by the Hudson's Bay Company posts in this region. Site descriptions are presented here to indicate the diversity of tree-ring sites in the Boreal Forest region in northern Quebec. As they become available after processing with an X-ray densitometry system, tree-ring data will be presented in subsequent publications. Part 2 (following) is the first of these reports.

The major objective in collecting, processing and presenting the white spruce tree-ring chronologies from the Cri Lake site is to provide summary chronologies that can be compared with other forms of proxy data for purposes of reconstructing past climate. Corollary objectives are to evaluate the dendrochronological quality of white spruce from the area and to produce tree-ring chronologies that can be used for dating purposes.

The raw-ring width and density data comprising the tree-ring series contain several components. To make this preparation of the data most useful for the stated purposes, we will define three components that seem to be present in all of the tree-ring series that we have observed through the years. These components are: (1) growth trend from pith to bark (the "A" component); (2) short-term fluctuations, greater than 10 years in length and shorter than the ring series of the tree being studied (the "B" component); and (3) year-to-year fluctuations, with all fluctuations greater than 10 years removed from the series (the "C" component).

On the basis of visual comparisons, the Cri Lake white spruce trees seem to provide the best quality chronologies for the area, but this will be determined in more detail after the other sites are processed.

For the Cri Lake material, an effort has been made to establish a standard format for processing the tree-ring data that can be followed for processing material from other sites in the area. The new approach of breaking the chronologies down into components and producing summary "A", "B", "C", and "B & C" chronologies may prove useful in providing more information about the relationships between tree-ring data and climatic factors.

Excerpts

669. PASTOURET, L., G.A. AUFFRET, M. HOFFERT, M. MELGUEN, H.D. NEEDHAM, and C. LATOUCHE. 1975. Sedimentation sur la Ride de Terre-Neuve. Canadian Journal of Earth Sciences 12(6):1019-1035.

The stratification, in part more or less rhythmic, of a fifteen metre long core of predominantly hemi-pelagic sediment from the northern slope of the Southeast Newfoundland Ridge reflects changing distribution patterns of different water masses during the late Quaternary. In particular, the lithological and microfaunal characteristics of the sediments indicate that, in the area of the core, the cold Labrador Current from the north and the continental slope water have had a permanent influence on the sedimentation pattern, whereas the paths of the Gulf Stream water have shifted intermittently. The influence of the Gulf Stream is clearly identifiable during the Holocene and during the last interglacial (faunal zone X). Ice-rafted debris and relatively coarse turbidite-type beds are more prominent in sequences deposited under a glacial regime, notably in those that accumulated near the end of the late Pleistocene and the beginning of the Holocene. The upper limit of faunal zone X (Sangamon-Würm) is placed close to 1000 cm depth in the core on the basis of the disappearance at this level of *Globorotalia tumida flexuosa* (Koch). The resulting estimate of the subsequent mean sediment accumulation rate is of the order of 10 cm/1000 yr.

A.A.

670. PATERSON, W.S.B., R.M. KOERNER, D. FISHER, S.J. JOHNSEN, H.B. CLAUSEN, W. DANSGAARD, P. BUCHER, and H. OESCHGER. 1977. An oxygen-isotope climatic record from the Devon Island ice cap, Arctic Canada. Nature 266(5602):508-511.

Isotope measurements on two adjacent cores through the Devon Island ice cap provide a well-dated climatic record for the past 5000 yr. Fluctuations in annual values include much 'noise', and ice flow over a rough bed produces distortions in the lowest 5% of core which covers roughly 120,000 yr. Comparison with the Camp Century, Greenland, record helps to separate climatic changes from changes in ice thickness or flow pattern.

A.A.

671. PAYETTE, S. 1976. Succession écologique des forêts d'épinette blanche et fluctuations climatiques, Poste-de-la-Baleine, Nouveau-Québec. Canadian Journal of Botany 54(12):1394-1402.

The stand structures of three white spruce (*Picea glauca* (Moench) Voss) climax forests of the hemiarctic zone in New Quebec are described. The forests have a similar structural pattern, characterized by important and irregular variations in the number of individuals per age, diameter, and height classes. These variations are synchronic and suggest that the climate strongly influences the forest regeneration. The discontinuous trend in the curves may possibly be related to changes in seed production and seedling establishment. Synchronism between the 300-year dendrochronological curve and the stand age-structure is apparent. The hollow parts of the age curves are related to unfavourable climatic periods and the peaks to favourable ones. These climatic fluctuations are probably responsible for either a decrease or an increase in white spruce seed production important to hemiarctic forest regeneration. Finally, the writer suggests a theoretical age-structure curve for climax forests in the maritime forest-tundra near Poste-de-la-Baleine, New Quebec.

A.A.

672. PAYETTE, S., et R. LAJEUNESSE. 1980. Les combes à neige de la Rivière aux Feuilles (Nouveau-Quebéc): indicateurs paléoclimatiques Holocènes. Géographie physique et Quaternaire 34(2):209-220.

On the basis of plant macrofossil analysis (charcoals, charred cones of black spruce *Picea mariana* (Mill.) BSP and larch *Larix laricina* (DuRoi) K. Koch, wood fragments) and plant population dynamics, the origin and the evolution of the snow-patch environment are correlated with the Neoglacial episode. Data suggest that this peculiar environment has evolved from previously wooded stands. The removal of the forest cover was caused by fires during cold climatic periods that restricted forest regeneration. The snowpatches therefore are thought to be a response to several periods of climatic deterioration around 2600, 2200, 1600-1400, 1000-900 and 500-300 years BP. Some snowpatches that appeared early during the Neoglacial may have experienced a minor tree invasion around 1300-1200 years BP, during a warmer climatic interval. The gradual development of snowpatch communities, and the overall regression of the forest cover since 2600 years BP, suggest that the climatic deterioration, although persisting, was not of great range; forest fires have played some role in the snow cover expansion, and may have initiated them. Snowpatches located near forest formations have experienced a larch colonization between 1940 and 1970, which seems to be correlated with the twentieth century warming trend. Since 1970, a reversal of this trend has been observed, and it is characterized by at least 17% of larch mortality in the snowpatch population. This mortality appears to be related to the reactivation of periglacial process. Finally, the recent formation of large gelifluction lobes along some snowy slopes had detrimental effects on lowland vegetation, and may eventualy produce suitable conditions for new snowpatch initiation.

A.A.

673. Pedology and Quaternary Research. Edited by: S. Pawluk. University of Alberta Press, Edmonton. 218 pp. 1969.

"The symposium is primarily concerned with presenting a series of review papers that should help in providing a better understanding as to how pedological principals may be applied to solving problems concerning the Quaternary. Special emphasis is placed on research methodology and application. Papers dealing with interdisciplinary studies related to Quaternary pedology are also included." [Individual papers have been separately abstracted.]

Excerpts⁺

674. PENTLAND, R.S. 1981. Climate change in Saskatchewan. In: Climatic Change Seminar Proceedings. Regina, March 17-19. Canadian Climate Centre, Downsview. pp. 79-82.

A borderline climate and a dominantly agricultural economy make Saskatchewan susceptible to the vagaries of climatic change.

Research and extension work and some structural measures have shown us a great deal about how to live with our climate and how to minimize the adversities of droughts and floods. There is no doubt that there is much more to be done in these areas before we will be satisfied that we are making the best use of our climatic and related land resources.

Data deficiencies, particularly in the North, need to be overcome because the North of Saskatchewan is going to be rapidly converted from a frontier to an integral part of the province's economy in the next few years.

Data on climate and its inter-relationship with economic and social development must be not only collected, but used to protect from potential setbacks and to permit continued growth and improvement.

A.C.

675. PERRY, A.H. 1974. The downward trend of air and sea surface temperatures over the North Atlantic. Weather 29(12):451-455.

The expansion of the polar vortex, and the displacement of cyclonic activity over the North Atlantic to lower latitudes have been accompanied by widespread negative sea temperature anomalies. The mean sea surface temperature for the late 1960s at the nine ocean weather ships considered together was nearly 1 deg C lower than in the early 1950s. These anomalies have in turn, been responsible for producing several seasons of anomalous atmospheric circulation e.g. the summers of 1968, and 1972. The ocean-atmosphere system, however, includes such a complex feedback between the two media that cause and effect are often difficult to separate.

G.A.

676. PETTAPIECE, W.W. 1969. The forest-grassland transition. In: Pedology and Quaternary Research. Edited by: S. Pawluk, University of Alberta Press, Edmonton. pp. 103-113.

Considerable controversy exists over the interpretation of the forest-grassland transition zone as an indicator of past environment. Our present knowledge of the transition soils of the Great Plains region of Canada and their distribution does not necessarily indicate any major climatic changes in the last few millenia. Most of the observed soil phenomena can be explained in terms of minor climatic variations of short duration. Particularly important here may be periods of drought and associated widespread burning.

A.A.

677. PETTAPIECE, W.W., and S.C. ZOLTAI. 1974. Soil environments in the western Canadian subarctic. In: Quaternary Environments: Proceedings of a Symposium. Edited by: W.C. Mahaney. First York University Symposium on Quaternary Research. Geographical Monographs No. 5:279-292.

An integrated surficial geology-soils-vegetation study was recently completed in the subarctic of northwestern Canada. This investigation, prompted by energy concerns in the north, revealed much new information about the relationships between soils and other aspects of the environment.

The mean annual temperature is well below freezing in the northern taiga of the subarctic, and where any insulating mat is present, the ground is perennially frozen. Nearly all of the medium and fine-textured soils have permafrost within 1 m of the surface and are strongly affected by cryoturbation. The result is a hummocky microrelief and a cyclic soil body that includes widely different profiles below the hummock and trough. The soil-climate and cryic processes also vary greatly across the microrelief, strongly affecting the species distribution within the scrubby black spruce-lichen forest. Thus sphagnum mosses commonly occur in the wet depressions, tall shrubs and trees on the sides of the hummocks, and small shrubs and lichens on the relatively dry crests. This kind of soil development, and its associated environmental implications, dominates in the subarctic west of the Canadian Shield. Changes have been proposed in the System of Soil Classification of Canada to recognize these and other permafrost soils in a new order, the Cryosolic Order.

By contrast, the coarser-textured, well-drained deposits contain no permafrost and have a much warmer and drier soil environment. This is reflected in a white spruce-birch forest cover and degraded, non-cryoturbated soils characteristic of the more southern boreal regions.

Forest fires can effect a variety of changes in the soil climate which result in accommodating shifts in the other environmental components.

Organic soils of the subarctic also have characteristic features. These include landforms such as peat plateaus and palsas (Zoltai and Tarnocai, 1971) and the growth of ice wedges in polygonal networks. The associated surface materials are dominantly fibric sphagnum peats. Layers of mesic sedge peat indicate periods of no permafrost but they are a natural part of the cyclic growth of these forms and may not represent climatic shifts. However, the lower portions of nearly all the organic sections are much more humified or decayed and could indicate a significantly warmer climatic period, presumably the Altithermal. Preliminary C^{14} dates suggest that present environmental conditions were established by 2,500 to 3,000 yrs. BP.

A complete understanding of present processes and features is definitely necessary for proper interpretation of past environments. This also applies to such fields as archaeology because most human activity is influenced by physical surroundings and in the subarctic soil phenomena such as the presence or absence of permafrost and cryic processes are important considerations. It is concluded that soil environments in the Canadian subarctic, which are indicated by the kind and degree of pedologic development, are a fundamental link in the complete chain of environmental components, including man.

A.A.

678. **PHEASANT, D.R., and J.T. ANDREWS. 1973. Wisconsin glacial chronology and relative sea-level movements, Narpaing Fiord-Broughton Island Area, eastern Baffin Island, N.W.T. Canadian Journal of Earth Sciences 10(11):1621-1641.**

Three distinct glacier advances and four major periods of adjustment of relative land and sea levels are recognized in the Wisconsin age stratigraphic and geomorphologic record of the Northern Cumberland Peninsula. The coast, which is presently undergoing submergence, is close to an isostatic equilibrium position following rapid land emergence during post-Cockburn time (ca. 8000-1000 BP). Laurentide ice advances during two earlier stades--the Alikdjuak ca. 115,000 BP and the Napiat >40,000 BP--were more extensive than the Cockburn glacier advances and a positive relationship between ice load and amount of crustal deflection at the ice margin is demonstrated. Computations based on synchronous raised marine features and known extent of the ice load indicate a crustal flexural parameter (∞) of >80 km and perhaps >135 km for this area. The date of the Alikdjuak stade suggests the time transgressive nature of the early-Wisconsin maximum position of the continental ice sheet margin and supports the hypothesis that continental glaciation may well have originated in the climatically sensitive uplands of the eastern Canadian arctic/subarctic.

A.A.

679. **POORE, R.Z. 1975. Late Cenozoic planktonic foraminiferal biostratigraphy and paleoclimatology of the North Atlantic Ocean: DSDP Leg 12. Ph.D. Thesis, Brown University. 207 pp. Dissertation Abstracts International 37(1):138B.**

This thesis consists of three separate but related studies aimed at increasing our knowledge of Late Cenozoic biostratigraphy and paleoclimatology in the high-latitude regions of the North Atlantic Ocean.

Pliocene and Pleistocene age sediments were covered at three sites in the Labrador Sea (111, 112, and 113). The Late Pliocene and Pleistocene fauna is less diverse and tropical forms are rare, being essentially restricted to carbonate intercalations in Late Pliocene glacially-rafted detrital sediments. No evidence of Gulf Stream influence is seen from Pleistocene levels in the Labrador Sea.

Quantitative analysis of the Pliocene-Pleistocene planktonic foraminiferal assemblages at Site 116 suggests the following: 1) A cooling event is indicated in the lower Pliocene (latest Miocene?). This event is not accompanied by ice-rafted detritus, and thus we infer that no significant continental glaciation took place in Northern Europe at this time. 2) Subpolar conditions prevailed in the area of Site 116 during most of the Pliocene and in the lowest part of the Pleistocene. 3) During most of the Pleistocene, conditions analogous to today (interglacial) in the area of Site 116 were either infrequent, of short duration, or both.

pD.A.I.

680. **POORE, R.Z., and W.A. BERGGREN. 1973. Pliocene-Pleistocene biostratigraphy and climatology of the Labrador Sea; calcareous plankton. Geological Society of America, Abstracts with Programs 5(7):769-770.**

Sediments of Pliocene and Pleistocene age were recovered at sites 111-113 in the Labrador Sea on DSDP Leg 12. A time framework is provided by paleomagnetically calibrated biostratigraphic datum levels. ...The late Pliocene and Pleistocene fauna is less diverse and tropical forms are rare and essentially restricted to carbonate intercalations in late Pliocene glacially rafted detrital sediments. ...Semi-quantitative analyses of the planktonic foramimifera indicate that the Pliocene-Pleistocene can be broadly characterized by four faunal assemblages. When plotted against "absolute age", the distributions of these assemblages suggest ...the Gulf Stream was excluded from the Labrador Sea during the Pleistocene.

pA.A.

681. **POPLAWSKI, S., and P.F. KARROW. 1981. Ostracodes and paleoenvironments of the late Quaternary Don and Scarborough Formations, Toronto, Ontario. Canadian Journal of Earth Sciences 18(9):1497-1505.**

Type section exposures at the Don Valley brickyard and Scarborough Bluffs were studied for ostracode occurences. In all, 12 species were identified from the Don Formation, with *Candona rawsoni* and *Candona caudata* being most abundant. A deltaic environment, with a mixture of fluvial and lacustrine species, is indicated at the brickyard, whereas a more dominantly lacustrine environment, with fewer ostracode species, is evident at the bluffs. Climatic conditions are consistent with those of other fossil groups in suggesting conditions rather like the present.

The Scarborough Formation has yielded only four species of ostracodes, with *Candona caudata* the most abundant. A much colder lacustrine environment is indicated for the Scarborough than for the Don Formation.

A.A.

682. **PORTER, S.C. 1979. Glaciological evidence of Holocene climatic change. International Conference on Climate and History, University of East Anglia, Norwich, July 8-14, Review Papers. pp. 148-179.**

Because glaciers typically respond to changes in their climatic environment by growing or shrinking in size, they can be used as sensitive paleoclimatic indicators. Evidence gained from studies of ice cores and glacial deposits makes it possible to construct continuous and discontinuous time series from which both the direction and magnitude of climatic change can be inferred. However, glacier surges unrelated to climate, lags in the dynamic response of a glacier terminus to a climatic change, and chronological uncertainties that result from problems in dating glacial deposits make assessment of the climatic significance of glaciological data difficult. In few areas do historical observations extend back beyond the 19th century, so the history of glacier activity commonly is reconstructed from morainal evidence and dated by radiocarbon, dendrochronology, or lichenometry. Radiocarbon dates frequently are ambiguous due to variations in the atmospheric production rate of ^{14}C, and uncertainties in the lag time between moraine stabilization and establishment of tree seedlings often render tree-ring dating of limited value, however, fast-growing lichens may offer a basis for assigning close minimum limiting ages to glacial deposits that are less than several thousand years old.

Evidence for repeated fluctuations of glaciers during the "Little Ice Age" of the last 4 to 5 centuries is widespread in glaciated alpine regions. Most glaciers achieved maxima in the 17th, 18th or 19th centuries and began a period of marked recession during the second half of the 19th century. Apparent nonsynchrony of second-order advances among geographic areas may reflect different climatic histories, differences in response lags of temperate and subpolar glaciers, or uncertainties in dating. Earlier intervals of glacier expansion similar in magnitude to the "Little Ice Age" centered close to 1100-1200, 2800-3000 and 5000-5300 years ago in a number of areas, but as yet no convincing well-dated global pattern has been demonstrated. During glacial maxima the snowline typically was lowered ca. 100-200 m, representing a depression equivalent to about 15% of that at the maximum of the last glaciation.

An inadequate data base severely restricts any attempt to make a comprehensive global synthesis of Holocene glacier fluctuations. With additional carefully collected information from selected sites along three major latitudinal and longitudinal transects, important insights can be gained regarding the intra and inter-hemispherical sychrony and relative magnitude of glacier advances, possible periodicities of glacier variations and their causes, the extent of ice recession between advances, and the magnitude and climatic significance of snowline fluctuations.

A.A.

683. POTZGER, J.E. 1953. Nineteen bogs from southern Quebec. Canadian Journal of Botany 31(3):383-401.

The 19 pollen profiles from the Gaspé and the St. Lawrence Valley show close correlation with known facts in glacial geology of this region. Marine invasions and persistence of the Laurentian icecap prevented forest occupation until climate had warmed considerably. The warm period was followed by a deteriorating climate as shown by rise in spruce and fir. During the succeeding very warm period, spruce and fir became rare, pine increased in the Gaspé region, and hemlock and broadleaved trees associated with pine became important in the St. Lawrence Valley, while the forests on the lower Laurentian Shield were composed primarily of pine penetrated by hemlock and broadleaved genera as minor elements. During most recent times the climate has become colder. Spruce and fir show a decided peak, especially in the Gaspé and on the Shield, pine declined in all parts of Quebec, but broadleaved genera, including chestnut in some areas, became prominent in the St. Lawrence Lowland, while decline of hemlock and pine and increase of spruce, fir, and yellow birch mark the forests on the southern slopes of the Shield. Pollen profiles are favorably correlated with forest divisions of Halliday.

A.A.

684. POTZGER, J.E., and A. COURTEMANCHE. 1954. A radiocarbon date of peat from James Bay in Quebec. Science 119(3104):908.

Peat material from the bottom level of a bog near Rupert River (51°28'N. 78°45'W.) showed a radiocarbon age of 2,350 ± 200 years. The C-14 dating is part of a study made in summer 1953 which indicates that forests migrated northward during the warm-dry post-glacial times, but have since withdrawn southward some 350 miles.

A.B.

685. POTZGER, J.E., and A. COURTEMANCHE. 1954. Bog and lake studies on the Laurentian Shield in Mont Tremblant Park, Quebec. Canadian Journal of Botany 32(5):549-560.

From the forest type indicated at lowest levels we must infer an initial warm period. This is attributed to ocean invasion of the St. Lawrence Valley and slow retreat of continental glaciers. The combination of these factors delayed the forest invasion of the Canadian Shield until the boreal spruce-fir period, so characteristic of lowest levels in bogs farther south, had passed. Slight deterioration of climate thereafter with development of local glaciers on the Shield apparently accounts for the first minor rise of spruce and fir. A warm-dry period at mid-profiles is indicated by the universal prominent pine peak accompanied by extreme decline of spruce and fir. The succeeding increase in hemlock and white-red pine (later replaced by minor peaks of beech-maple) suggests a moister climate with increasing coolness. Continued cooling during more recent times in turn favored spruce, fir, and yellow birch. Pine, hemlock, beech, and oak declined to a status of minor elements in the forest association. The erratic fluctuations of paper birch and its abundance at all levels show little correlation with major climatic changes.

A.A.

686. POTZGER, J.E., and A. COURTEMANCHE. 1956. Pollen study in the Gatineau Valley, Quebec. Butler University Botanical Studies 13(1):12-23.

Pollen frequencies in the deposits of five bogs covering a radius of about 50 miles in the Gatineau Valley of Quebec were determined by conventional methods of pollen analysis. It is concluded that the Gatineau Valley was one of the most important routes for plant migration during early post-glacial times. An initial warm period (similar to that of all southern Quebec) is suggested by highest abundance of oak in the first or second foot-level and pine forest cover with very low spruce fir. Cooling climate followed soon, marked by a decided increase in abundance of spruce. Succession is similar at all five bogs. Pine, (low oak peak) to pine-spruce, to Jack pine, while spruce and fir decreased to negligible representation, to white-red pine with minor hemlock peak, to pine-spruce-fir-birch which suggests cooling climate during the recent past. The Gatineau Valley apparently differs climatically from all of southern Quebec and the Mont Tremblant Park region, which cannot be attributed to latitude alone.

A.S.

687. POTZGER, J.E., and A. COURTEMANCHE. 1956. A series of bogs across Quebec from the St. Lawrence Valley to James Bay. Canadian Journal of Botany 34(4):473-500.

The study includes 19 bogs between 45° 07'N and 51° 59'N, spaced at about 50 mile intervals from the St. Lawrence Valley across the Laurentian Shield to James Bay (Jack River).

Up to lat. 47°N five major climatic changes are recognized for Quebec and are referred to as Q-1 to Q-5. The pollen profiles suggest that an initial, pronounced warm period (Q-1) (correlative with the Lake Timiskaming retreat) followed by cooling (Q-2), very likely also accompanied by local glaciation (correlative with the Cochrane halt), prevailed from the St. Lawrence Valley to Lac Soscumica bog (50° 39'N). The initial warm period is marked by prominent pine peaks accompanied by an impressive minor oak peak. During the major xerothermic period (Q-3), all bogs record a very long and prominent pine climax, with replacement of *Pinus banksiana* by the white-red pine group up to the Lacroix River bog (49° 02'N). From Clova (48° 07'N) to Jack River bog (51° 59'N) jack pine replaced red-white pine, while the upper half of the profile accumulated. This shows jack pine with a striking bimodal pattern of representation. Also, north of Clova, jack pine formed an important association with *Picea mariana* during the more recent past, introducing the forest type which prevails up there today. From the St. Lawrence Valley (45° 07'N) to the lower edge of the Shield at Saint-Lin (45° 55'N) white-red pine held an important place in the forest cover up to the present. The single most striking feature of the study is that red-white pine penetrated as important forest associates to the Rupert River (51° 28'N). No doubt white-red pine extended their range northward during the prominent warm-dry period (Q-3) because their highest representation appears in the lower levels of bogs. The great change in vegetation type, with more emphasis on boreal species *Picea mariana* and *Pinus banksiana*, from Clova (48° 07'N) northward to James Bay suggests the Cochrane oscillation influence and subsequent retreat during the ensuing major xerothermic period (Q-3). This period had probably waned by the time the forests were able to invade the James Bay region, thus giving rise to a rather monotonously changeless forest history from lat. 50° 54' northward (Q-5).

Local glaciation is indicated in the bog from Mont Tremblant (Bog 14), where forest history began during the xerothermic period. Figure 2 presents the highest percentage attained by species at a given latitude, which at a glance divides the species according to latitudinal preference, suggesting temperature control.

A.A.

688. POWELL, J.M. 1981. Impact of climatic variation on boreal forest biomass production. In: Climatic Change in Canada 2. Edited by: C.R. Harington. Syllogeus 33:189-194.

The two overall objectives of the study are to determine: (1) extent and degree of past short- and long-term climatic variation in selected regions of the Boreal Forest to assess impact of climatic change upon tree and forest growth; (2) quantitative and qualitative relationships between key climatic parameters/climatic variations, and measures of forest biomass growth and production in selected regions of the Boreal Forest.

All long-term instrumental climatic records available for the central Boreal Forest zone (Yukon to northwestern Ontario) will be analyzed to establish regional climatic (particularly temperature and precipitation) trends and fluctuations. In addition, proxy data relating to the Boreal Forest zone will be used (e.g. data from dendrochronology, paleobotany, lake sediments including foraminifera, speleothems, isotopes, archaeology and historical documents). This will help to establish climatic variations over a longer period.

Excerpts

689. POWELL, L.B. 1932. Tree rings and wheat yields in southern Saskatchewan. Monthly Weather Review 60(11):220-221.

The author studied radical tree growth at two points in southern Saskatchewan in an attempt to find a relationship between tree growth and wheat yields. Crop records date back to 1898, meteorological records to 1883, and a tree ring chart to 1763. He found that there has been enough moisture in southern Saskatchewan to grow trees for the last 150 years, and that extremely poor years have been the exception. He found some relationship between tree growth and wheat yields, especially when one third of each year's growth was carried over to the next year to allow for the conservation of energy in the tree or soil moisture or both. The only important cycle found was one of over 50 years, and the lack of short cycles made prediction of wheat yields from tree growth impossible.

Thomas

690. PREST, V.K. 1977. General stratigraphic framework of the Quaternary in eastern Canada. Géographie physique et Quaternaire 31(1-2):7-14.

In eastern Canada, interglacial and interstadial deposits have been reported from Nova Scotia and Quebec, but in the other provinces only Wisconsinan deposits. In Nova Scotia, pollen from some organic deposits buried beneath one or more tills, indicates a warm, interglacial climate--presumably the Sangamon Interglacial Interval. Other buried organic deposits, in contrast, indicate a cool, boreal forest environment. As radiocarbon analyses have given 'greater than' dates the deposits are considered to be early Wisconsinan. The interval is tentatively correlated with the St. Pierre Interstadial of Quebec. The only known mid-Wisconsinan deposit is at Salmon River on St. Mary's Bay, in southwestern Nova Scotia, where the marine shells have been dated at 38,600 ^{14}C years. Elsewhere in both coastal and interior Nova Scotia multiple till sections suggest a more or less continuous ice cover throughout the Wisconsinan. In Quebec, there is a very limited, but nevertheless important, record of the Sangamon Interglacial Interval. Compact clayey rhythmites in the Harricana River Basin, close to James Bay, appear to correlate with the lacustrine member of the Missinaibi Formation farther west in Ontario. In southern Quebec, there is another indication of interglacial deposits for the oldest sediments exposed in the Sherbrooke region and in the Upper Chaudiere River Valley beneath the lowest of three Wisconsinan tills. These deposits were weathered and cemented prior to deposition of the oldest till. As the gravels contain pebbles of Laurentian Shield gneiss there obviously was a pre-Sangamon glaciation. These two areas contain the most complete stratigraphic record of the Wisconsinan yet established in Quebec.

A.A.

691. PREST, V.K., and D.R. GRANT. 1969. Retreat of the last icesheet from the Maritime Provinces-Gulf of St. Lawrence region. Geological Survey of Canada Paper 69-33:1-15.

The popular concept of overriding Laurentide ice (Labradorean sector) in the Maritime Provinces-Gulf of St. Lawrence region is examined in terms of regional ice-flow patterns and other supporting data--and is found wanting. A reinterpretation of the data, the glacial lineations and other features presents a picture of localized, more or less radial outflow from certain upland and lowland areas. The pattern of ice-flow features and end moraines is shown to relate to a rising sea level over the period from about 18,000 to 11,000 years BP. The maritime climatic regime enabled various parts of an Appalachian ice complex to remain active as the sea encroached on the depressed land masses. The deeper-water parts of the submerged coast served as 'leads' into the ice fronts, with consequent development of calving bays and ice drawdown.

It is concluded that Laurentide ice was not as active over the Maritime Provinces as has generally been believed and that the growth of Appalachian glaciers during the build-up of the last continental ice sheet may have effectively barred Laurentide ice from some parts of the region. Laurentian Channel served as an outlet that diverted Laurentide ice through Cabot Strait to Atlantic Ocean, so that Prince Edward Island and Cape Breton Island do not show a pattern of Laurentide ice flow, and the Magdalen Islands remained unglaciated.

A.A.

692. PREST, V.K., J. TERASMAE, J.V. MATTHEWS, Jr., and S. LICHTI-FEDEROVICH. 1976. Late-Quaternary history of Magdalen Islands, Quebec. Maritime Sediments 12(2):39-59.

The authors' objectives were "to study the geomorphology and surficial deposits of the Magdalen Islands, to interpret the stratigraphy, chronology and paleoenvironments of the deposits, and to determine the source areas of foreign stones (chiefly cobbles and boulders)". They review both past and present studies of the Islands.

Ten samples were collected from the buried peat deposits at Portage-du-Cap for palynological analysis. This preliminary evidence "indicates that environmental conditions during deposition of the Portage-du-Cap buried peat were perhaps more favourable than at any time during the Holocene and hence, an interglacial age for this stratigraphic unit is implied."

Macrofossils obtained from the Holocene sediments of eastern Amherst Island "represent the type of environment that occurs near poorly drained sites on the Magdalen Islands today." This is in marked contrast to the plant and insect assemblages of Portage-du-Cap, which tentatively indicate a climate warmer than that of the present.

Diatom analysis revealed a total absence of floral fresh-water forms and a near absence of true brackish taxa. The dominant component was marine littoral forms, indicating "deposition at or near a shoreline at a time when the sea was higher and probably warmer than at present; this was probably during an interglacial interval."

A.B.S.

693. Problems in Palaeoclimatology. Edited by: A.E.M. Nairn. Interscience, New York. 705 pp. 1963.

Contains 13 chapters, each dealing with a type of evidence. Chapters relevent to Canada are: the use of fossil plants in paleoclimatic interpretations; the recognition of ancient glaciations; geophysical techniques and ancient climates; theoretical considerations and Quaternary climates; paleontology and climate; and problems of sediments and soils.

L.G.

694. Quaternary Environments: Proceedings of a Symposium. Edited by: W.C. Mahaney. York University, Toronto. Geographical Monographs No. 5. 318 pp. 1974.

The First York University Symposium on Quaternary Research saw 15 papers presented on topics concerned with geology, geomorphology, pedology, and palaeoclimatology. Relevant papers have been separately annotated.

A.B.S.

695. Quaternary Geology and Climate. Edited by: H.E. Wright, Jr. Volume 16 of the Proceedings of the 7th Congress of the International Association for Quaternary Research. National Academy of Sciences, Washington, D.C. Publication 1701. 1969.

"...a selection of Congress papers, mostly by foreign authors, that treat various geologic and paleoclimatic subjects or regions in review." Relevant paper by Dzerdzeevskii annotated separately.

A.B.S.

696. Quaternary Paleoclimate. Edited by: W.C. Mahaney. Geo Abstracts, Norwich. 464 pp. 1981.

Thirteen articles having relevance to climatic change in Canada are annotated individually.

A.B.S.

697. QUIGLEY, R.M., and A. DREIMANIS. 1966. Secondary aragonite in a soil profile. Earth and Planetary Science Letters 1(5):348-350.

Soft scaly coatings of both aragonite and calcite were observed on sand and gravel particles at a depth of 0.6-1 m in a soil profile developed in a temperate climate in southern Ontario, Canada. The presence of the aragonite is believed to be related to warm soil temperatures and an abundance of Mg in the dolostone rich sand and gravel deposit. The presence or absence of aragonite may prove of value in differentiating between warm interglacial and cool interstadial soil profiles.

A.A.

698. QUIGLEY, R.M., and A. DREIMANIS. 1972. Weathered interstadial green clay at Port Talbot, Ontario. Canadian Journal of Earth Sciences 9(8):991-1000.

The geologic origin of a distinctive layer of green, weathered clay belonging to the lower part of the Port Talbot Interstadial sediments (Port Talbot I) on the north shore of Lake Erie has been reinterpreted in relation to its clay mineralogy, carbonate content, and pollen data.

In addition to illite and chlorite, both characteristic of all clayey glacial sediments in the area, the green clay contains abundant smectite probably produced by oxidation weathering of chlorite in the Bradtville Till. Carbonate contents, normally less than 1% in the green clay compared to values of 15 to 45% in the overlying and underlying sediments, indicate extensive solution weathering.

The green clay layer is interpreted to be an accretion gley, weathered in a soil profile during the early part of the Port Talbot Interstadial and subsequently eroded and deposited in poorly drained depressions under reducing conditions. An abundance of oak, pine, and spruce pollen indicate a fairly temperate climate at the beginning of Port Talbot I, becoming cooler towards the deposition top of the green clay, as suggested by low percentage or absence of oak pollen.

A.A.

699. QUINLAN, G., and C. BEAUMONT. 1982. The deglaciation of Atlantic Canada as reconstructed from the postglacial relative sea-level record. Canadian Journal of Earth Sciences 19(12):2232-2246.

The post-Wisconsinan relative sea-level record from Atlantic Canada is used to reconstruct the morphology of late Wisconsinan age ice cover during its retreat from the Atlantic region. The proposed reconstruction has little or no grounded ice in the southern Gulf of St. Lawrence, an ice dome over the north shore of the St. Lawrence, and thin ice, often less than 1 km thick, over much of the rest of the area. A sensitivity analysis shows that the proposed reconstruction is not unique in its ability to account for the relative sea-level record but that the thickness of ice in any individual area of the reconstruction is unlikely to be in error by more than a factor or two. The exact position of the ice margin in some areas is not well constrained by the model; an example is in southeastern Newfoundland.

The numerical model used to relate ice morphology to postglacial relative sea level assumes that the ice sheets are isostatically equilibrated at the glacial maximum and, therefore, that load changes associated with earlier ice-sheet growth may be ignored. This assumption is shown to be reasonable. The same rapid relaxation of the Earth that allows one to ignore the effects of glacial accumulation, however, prohibits one from recognizing the effects of large-scale ablation that may have occurred prior to the assumed glacial maximum. For this reason the proposed reconstruction may be representative of only a late stage in the ablation of much more extensive and thicker ice sheets.

Surfaces of relative sea level are presented for Atlantic Canada at various times in the past. These surfaces coincide with observational data where such data exist and are felt to provide reasonable estimates of relative sea level at all other locations for at least the last 13 000 years.

A.A.

700. RADFORTH, N.W. 1945. Report on the spore and pollen constituents of a peat bed in the Shipshaw area, Quebec. Transactions of the Royal Society of Canada, Series 3, Section 5, 39:131-142.

Tentatively the writer is inclined to a conclusion that the Shipshaw peat is interglacial and possibly Sangamon in age. That it is unlikely to be postglacial is supported by evidence given earlier. That it may be Sangamon in age is based chiefly on the favourable comparison with the Laura and Canton peats. However, the significance of this comparison must not be overstressed as the evidence is too incomplete.

Then too there is evidence for an alternative, more speculative view that the Shipshaw peat is Yarmouth in age. Coleman (1941) recorded that the interglacial forest of the Toronto formation which he regards as probably Yarmouth, indicates a climate of four or five degrees warmer than at present, and it is a higher temperature of this order that would be more conducive to success for the Shipshaw peat flora.

Excerpt

701. **RADFORTH, N.W., and J. TERASMAE. 1960. A palynological study relating to the Pleistocene Toronto formation. Canadian Journal of Botany 38(4):571-580.**

The present palynological study is used as a new approach to determine the stratigraphical and chronological position of the Pleistocene interglacial deposits, the Toronto formation, exposed in sections at Toronto, Ontario, Canada.

An interpretation of lithology, combined with evidence supplied by the pollen and spore assemblages, indicates that the Don beds, the lower member of the Toronto formation, belong to the Sangamon Interglacial. The Scarborough beds, the upper member of the formation, were deposited during a nonglacial interval, cooler than the present. Conformity between the two members is questioned on grounds of lithological and palynological evidence.

Results of palynological studies, as indicated by this investigation, can be used for interpretation of the mode of deposition of certain laminated sediments and for reconstruction of past types of landscape.

A.A.

702. **RAILTON, J.B. 1975. Post-glacial history of Nova Scotia. In: Environmental Change in the Maritimes. Edited by: J.G. Ogden, III and M.J. Harvey. Proceedings of the Nova Scotian Institute of Science 27(Supplement 3):37-41.**

The author reviews known dates of post-glacial stratigraphy and evidence for important climatic changes. The first closed boreal-type forests (spruce, fir, and birch) appear to have occurred in Nova Scotia around 10,000 years B.P.; the average date for the spruce post-glacial pollen zone (A zone) is 9821 years B.P. The author provides the average date and range of classical zones A,B,C1,C2,C3. Although these are not contained in all the lakes and bogs examined, those zones represented by the spectra examined show the classical sequence of climatic changes. The A/B transition, spruce replaced by pine, occurred in Nova Scotia about 7300 years B.P. The hypsithermal interval, maximum warmth and dryness, spanned the period between 8700-5000 years ago. Work done in southwestern Nova Scotia indicates a temperature rise to an optimum and then a climatic deterioration.

A.B.S.

703. **RAMPTON, V. 1971. Late Quaternary vegetational and climatic history of the Snag-Klutlan area, southwestern Yukon Territory, Canada. Geological Society of America Bulletin 82(4):959-978.**

Present vegetation in the Snag-Klutlan area has a general altitudinal zonation; tree line being between 4100 and 4400 ft elevation on almost all slopes. Pollen spectra from surface samples below tree line generally reflect the vegetational composition. Those from above tree line, however, do not always reflect the surrounding vegetation, because they contain a large amount of pollen originating from below tree line.

A pollen diagram from pond sediments suggests the following vegetational sequence for the last 31,000 yrs: 31,000 B.P. through 27,000 B.P., fell-field or sedge-moss tundra followed by shrub tundra; 27,000 B.P. through 10,000 B.P., sedge-moss tundra; 10,000 B.P. through 8700 B.P., shrub tundra; 8700 B.P. through 5700 B.P., spruce woodland; 5700 B.P. through present, spruce forest. The diagram also suggests the following negative departures of July temperatures: 31,000 B.P. through 27,000 B.P., at least 8°F and possibly as much as 16°F; 27,000 B.P. through 13,500 B.P., 13°; 13,500 B.P. through 10,000 B.P., 12°F; 10,000 B.P. through 8700 B.P., 8°F. Precipitation seems to have been lower during cooler intervals than are present levels. Precipitation also seems to have increased over the last 6000 years.

Logs above the present tree line imply that summer temperatures have fluctuated above present values between 6000 B.P. and 1220 B.P. Tree-ring studies indicate that temperatures during the 200 yrs preceding 1940 were as much as 2°F cooler than present.

A.A.

704. REEVES, B.O.K. 1973. The nature and age of the contact between the Laurentide and Cordilleran ice sheets in the western interior of North America. Arctic and Alpine Research 5(1):1-16.

The presumed existence of a single mass of coalesced Cordilleran and Laurentide ice during most of late Wisconsin time is central to many archaeological hypotheses on the peopling of the New World. The area under concern is a 2,400-km belt of the Western Interior Plains and adjacent mountains, extending from the 49th parallel to the Arctic Ocean. Multiple Cordilleran glaciation occurred in the Rocky Mountain area during both late and early Wisconsin time. Radiocarbon dates indicate the mountain valleys were largely ice-free by 10,500 BP. Multiple Laurentide glaciation also is well established, the last advances in southern Alberta (late Wisconsin) having terminated east of the mountain front. Southern Alberta and southwestern Saskatchewan were ice-free by ca. 15,000 BP. Incontravertible evidence for coalescence west of the late Wisconsin ice front comes only from the Athabasca Valley, where Roed found that the two glaciers coalesced and flowed southeast. This event occurred either in early Wisconsin or Illinoian time. Since then the western border of the plains of Alberta has remained ice-free.

A.A.

705. REEVES, B.O.K. 1975. Early Holocene (ca. 8000 to 5500 B.C.) prehistoric land/resource utilization patterns in Waterton Lakes National Park, Alberta. Arctic and Alpine Research 7(3):237-248.

Archaeological research in Waterton Lakes National Park, Alberta, between 1967 and 1971 located 12 archaeological sites dating in the interval between ca. 8000 and 5500 B.C. Ten of these were tested and two excavated. The location of these sites is examined in relation to the late glacial-early Holocene environmental sequence, and various present-day variables--climate, physiography, vegetation, and ungulate behavior, and hydroseres which structured the more recent seasonal prehistoric settlement patterns in the Park. The data suggest that a settlement pattern characterized by seasonal use of the various valley areas and resources was established by ca. 6000 B.C.

Late Pleistocene time contains two major glaciations, Bull Lake and Pinedale. Bull Lake dating in the Yellowstone Park area from ± 70,000 to ± 120,000 BP (Birkeland et al., 1971) is represented by two major advances in Waterton.

Pinedale dating from ca. 20,000 B.C. (Birkeland et al., 1971) to 6000 B.C. (Reeves and Dormaar, 1972) generally consists in Waterton of four ice frontal positions.

The climate of the Pinedale III/IV interval is not particularly well known in the northern Rockies, since the older, radiometrically uncontrolled, pollen profiles available for areas such as Glacier National Park (Hansen, 1949) and Jasper National Park (Heusser, 1956) only differentiate major post-Pleistocene trends. Unfortunately current palynological data for Waterton postdates the time period under consideration in this paper. While local data are lacking, data from south-central British Columbia indicate that the timberline in that area was at least 300 m above its present position at 7200 B.C. suggesting a drier and warmer climate (Van Ryswyk, 1971). If climate fluctuations are longitudinally time correlative in the Northern Cordillera, one may infer that similar climatic conditions were extant in Waterton at this time. Perhaps that atmospheric circulation pattern was similar to that which existed during the later Atlantic climatic episode (Reeves, 1973).

Environmental conditions during Pinedale IV time are better delineated. Data obtained from the "Gap", a site 60 km north of Waterton indicate the upper timberline was depressed at least 600 m from its present position at 2,200 m. Mean annual temperatures decreased 3 to 4°C, and precipitation doubled (Reeves and Dormaar, 1972). Similar data have been obtained from the Crowsnest Valley, located between the Gap and Waterton (Reeves, 1974).

The Pinedale IV landscape in Waterton differed from that of today in a number of major aspects. Large areas of the mountain valleys were covered by ice. The alpine life zone ... was also greatly expanded.

The Atlantic climatic episode dating ca. 6000 to 3000 B.C. follows Pinedale IV's advance and retreat. Current palynological data (Hills, 1971) from Waterton indicate that the most marked climatic change occurred during the interval prior to 3500 B.C. At this time the lower tree line shifted upwards at least 100 m. Data from the mountains to the north indicate an increase in mean annual temperature of 2°C, and a decrease in precipitation of about 25%, mainly through decreased winter precipitation (Reeves and Dormaar, 1972).

A.A.+

706. **REEVES, B.O.K., and J.F. DORMAAR. 1972. A partial Holocene pedological and archaeological record from the Southern Alberta Rocky Mountains. Arctic and Alpine Research 4(4):325-336.**

Salvage excavations at an archaeological site (DlPo-20) located in the Front Range of the Rocky Mountains in southwestern Alberta revealed the presence of a series of living floors, radiocarbon dated at ca. 4000, 4700 and 6000 B.C., in association with the Ah horizons of a series of buried soil profiles. While archaeological information is minimal, analysis of the buried soils indicates that they formed under a different vegetation cover from that on the site today. The earliest soil, a Degraded Alpine Eutric Brunisol, inferred to have developed under subalpine to alpine vegetation and a cold wet climate, suggests depression of the timberline on the order of 600 m. These climatic characteristics are considered to reflect those of the last valley glaciation (Pinedale IV). The two later buried soils, Orthic Regosols, developed under grassland vegetation reflective of a drier warmer climate, indicating the lower tree line shifted upwards a minimum of 30 m. A return to "normal" climatic conditions is correlated with the onset of the Neoglacial dated ca. 2800 B.C. in the Southern Alberta Rockies.

A.A.

707. **REIMHERR, G.W. 1979. Paleoclimatology, a bibliography with abstracts. National Technical Information Service, Springfield, Virginia. 92pp.**

The cited reports describe studies of climate in the geologic past, and involve the interpetation of glacial deposits, fossils, and paleogeographical data. [Search period covered 1964-November 1979. Contains 154 abstracts.]

A.I.+

708. **REITAN, C.H. 1974. A climatic model of solar radiation and temperature change. Quaternary Research 4(1):25-38.**

Mean monthly temperatures for the Northern Hemisphere were determined for the years 1955 through 1968 following the same procedures used by H.C. Willett, and J.M. Mitchell, Jr., in their studies of long-term trends. It was found that the downward trend they reported starting in the 1940s continued, though interrupted, into the 1960s.

The temperature data when combined with radiation data and other components of the hemispheric energy budget led to the formulation of the response ratio, the relationship between change in incoming solar radiation and change in temperature. When this response ratio was applied to decrease in direct solar radiation following the eruption of Agung in 1963, a probable cause-effect relationship was suggested.

A.A.

709. **REPENNING, C.A. 1980. Faunal exchanges between Siberia and North America. Canadian Journal of Anthropology 1(1):37-44.**

The microtine rodents, because of their rapid rate of evolution in recent geologic time, their arctic to temperate preferences, and their rapid rate of dispersal in appropriate environments, provide the most precise record of faunal movement between Siberia and North America. This record has been calibrated by radiometric dates, the paleomagnetic polarity scale, oceanic climatic indicators, and the similar history of microtine invasions from Siberia into Europe. The development of provincialism in the North American fossil microtine fauna clearly documents the effective beginning of the ice-free corridor east of the Cordilleran ice sheet. Between microtine dispersal events, Beringian Alaska had a Siberian fossil fauna bearing no relation to that of North America.

A.A.

710. **RICHARD, P. 1971. Two pollen diagrams from the Quebec City area, Canada. Pollen et Spores 13(4):523-559.**

The vegetation history has been reconstructed in two localities around Québec City, on the basis of pollen analysis. The chronological succession of the plant communities since deglaciation compares quite well with the present latitudinal vegetational zonation. The fossil flora of an arctic character, previously found by some authors, is reinforced here by the discovery of many additional taxa and by a remarkably high percentage of non-arboreal pollen.

A.S.

711. **RICHARD, P. 1973. Histoire postglaciaire de la végétation dans la région de Saint Raymond de Portneuf, telle que révélée par l'analyse pollinique d'une tourbière. Naturaliste Canadien 100(6):561-575.**

The pollen diagram gives the postglacial vegetational history for the last 8000 years. The whole late-glacial is lacking because of the geomorphological position of the bog on a late glacial outwash plain. The first vegetation is composed of herbs and shrubs, which were rapidly replaced by an open spruce community. Subsequently, a white birch-balsam fir community established itself and was replaced afterwards by a yellow birch-balsam fir community. Sugar maple stands containing yellow birch replaced fir stands and maintained themselves until present time. Difficulties were encountered in the reconstruction of past vegetation from the pollen diagram. A methodology is proposed which takes into account the type of landform and the results of present pollen rain studies of known plant communities.

A.A.

712. RICHARD, P. 1973. Histoire postglaciaire comparée de la végétation dans deux localités au nord du Parc des Laurentides, Québec. Naturaliste Canadien 100(6):577-590.

The regional vegetation history of the Montagnais site began with a tundra and was followed by a forest made up of exclusively boreal communities. A succession of spruce fir, and fir-white birch communities led to a rather uniform postglacial history of vegetation. The situation for the Kenogami site has been very different, since a number of thermophilous species played a role in the composition of past communities. Even if the initial tundra is lacking, the vegetational history shows much more variety. On the mesic sites, a fir-white birch community followed the initial spruce vegetation. After a return of spruce, a fir-yellow birch community was established and constituted the climax vegetation up to now. However, during this period, changes occurred on hydric sites in which american elm and black ash seem to have had the main role. The discovery of another pollen assemblage representing tundra brings new light on the still poor knowledge we have of this late-glacial vegetational formation.

A.A.

713. RICHARD, P. 1973. Histoire postglaciaire comparée de la végétation dans deux localités au sud de la ville de Québec. Naturaliste Canadien 100(6):591-603.

Vegetational history in the Dosquet region has been registered in peat deposits since about 9,000 B.P. At that time, the freshly water-free land supported spruce communities. These were replaced by a vegetation dominated by fir and white birch, which gave way to sugar maple-yellow birch community first and to sugar maple in association with more thermophilous taxa afterwards. This last situation prevailed until present. Pollen analysis of the "lac à Busque" sediments show evidence for the tundra from at least 10,000 to 9,300 years B.P. *Betula glandulosa* community replaced tundra and was rapidly overcome by spruce vegitation. A fir-dominated community, with white birch, succeeded the spruce and was followed by sugar maple-yellow birch forest which dominated until now. This study allowed in addition methodological considerations concerning some feature of the pollen curves of *Acer saccharum* and *Picea*.

A.A.

714. RICHARD, P. 1975. Contribution à l'histoire postglaciaire de la végétation dans la plaine du Saint-Laurent: Lotbinière et Princeville. La Revue de Géographie de Montréal 29(2):95-107.

After the retreat of Postglacial Champlain Sea from the southern part of the central St. Lawrence lowlands, vegetation took place in the following sequence: spruce stands, fir communities and later, sugar maple communities. The progressive warming of the climate, while the sea was still a barrier to plant immigration northward, provoked a "stand still" of the floral elements and resulted in an intermingling of different plant communities. This phenomenon is better expressed at Lotbinière. The great diversity of soil conditions allowed the boreal and meridional floral elements to grow nearly side by side. The same pattern of site control had a strong influence on the pollen representation of vegetation during the whole Postglacial. This work stresses the difficulties met to show possible fluctuations in the floristic composition of the "Laurentian" maple community in the past. The problem should be solved by the study of local sediments that have registered a very local pollen input.

A.A.

715. RICHARD, P. 1975. Contribution à l'histoire post-glaciaire de la végétation dans les Cantons-de-l'est: étude des sites de Weedon et Albion. Cahiers de Géographie de Québec 19(47):267-284.

The postglacial vegetational history in the region of Weedon has been studied by pollen analysis of peat bog and lake sediments. Initial tundra vegetation has been replaced by the forest, at about 11,000 B.P. Spruce established first, followed by fir stands (10,600 B.P.) and, last, maple communities (9,000 B.P.) on the mesic sites. The yellow birch (*Betula alleghaniensis*) seems to have experienced a delay in its immigration to the region. This contributed to allow the existence of an original type of initial maple community, in which the usual trees now found with maple were then lacking.

A.A.

716. RICHARD, P. 1976. Relations entre la végétation actuelle et la spectre pollinique au Québec. Naturaliste Canadien 103(1):53-66.

The pollen analysis of 59 moss polsters distributed throughout southern Quebec led to the characterization of the present vegetation at the climax domain level. Within a climax domain, different pollen spectra have been obtained, according to the distribution pattern of landforms and soils. Nevertheless, characteristic pollen spectra can be recognized for each climax domain. The tree species that give their name to the vegetation unit, reach their maximum pollen representation within the unit. Gramineae, *Ambrosia* and *Rumex* pollen are most widespread in the maple region because of high agricultural activities. A methodology for the interpretation of the pollen diagrams from Quebec is put forward, in the light of these results. Provided the autecology and sociological affinities of the plants did not change greatly during the postglacial, and when the climate did not change too fast, it is possible to trace the climax domains of the past when they correspond to the present spectra, or reconstruct other climax domains that could have existed.

A.A.

717. RICHARD, P. 1977. Végétation tardiglaciaire au Québec méridional et implications paléoclimatiques. Géographie physique et Quaternaire 31(1-2):161-176.

Recent pollen-analytical data allow a detailed reconstruction of the initial vegetation which followed the final retreat of the Wisconsinan ice sheet. The general scheme is the following: A period of periglacial desert was replaced more or less rapidly by tundra vegetation. Afforestation of the landscape proceeded either through a taiga phase, represented by a lichen-black spruce woodland, or by the establishment of an aspen parkland. Several postglacial vegetation types followed. The paleoclimatic interpretation of the data indicates severe climatic conditions around 11 400 BP at Mount Shefford, and around 7200 BP in the southern part of Laurentides Provincial Park. It has not yet been possible to show evidence for a climatic oscillation during the late-Glacial of Quebec, which appears very metachroneous. This metachroneity seems to be caused by the differences in altitude of the main physiographic regions and does not seem to correspond to the metachroneity in the ice retreat of the Wisconinsan ice sheet. ... There is now a firm basis to the statement that vegetation similar to the present-day tundra occupied a broad area in front of the ice sheet. Future research should define the duration and extension of the tundra on one hand, and on the other hand increase knowledge of its paleoclimatic significance.

pA.A.

718. RICHARD, P. 1977. Histoire Post-Wisconsinienne de la végétation du Québec méridional par l'analyse pollinique. Service de la recherche, Direction général des forêts, Ministère des Terres et forêts du Québec. (Publications et rapports divers) Tome 1, 312 pp., Tome 2, 142 pp.

This research aims at reconstructing the post-Wisconsinan vegetational history of south-central Québec. The effort has been placed on the pollen morphology of the Quebec flora, on the methodology of the interpretation of pollen diagrams in the Quebec context, and on the accumulation of pollen diagrams. This effort on pollen morphology allowed the improvement of the identifications in pollen analysis. A total of 21 pollen diagrams has been established from lake or bog sediments in the area. A small scale study of the relations between the pollen spectra and the present vegetation has been conducted. It shows the possibility of reconstructing past vegetation at the climax domain level, which greatly improves the interpretation of the pollen diagram in terms of vegetation. Reconstruction of past vegetation is then expressed in a system, the unit of which serves to describe the present vegetation cover. Results of this study and several methodological considerations are the keys to interpreting the pollen diagrams.

A.A.

719. **RICHARD, P. 1978. Histoire tardiglaciaire et postglaciaire de la végétation au Mont Shefford, Québec. Géographie physique et Quaternaire 32(1):81-93.**

Pollen analysis of a peat bog at Mount Shefford revealed an initial lake stage from about 11,400 to 4,200 BP. The site was subsequently occupied by a bog dominated by Ericaceae and *Myrica gale*, then by an alder thicket (*Alnus rugosa*) and finally by a forest dominated by red maple (*Acer rubrum*). The history of the regional vegetation is the following: before 11,400 years BP, a cold desert preceded an herb tundra and then, a shrub tundra that ended at 11,100 BP. The afforestation was characterized first by open stands of spruce (*Picea mariana*) and aspen (*Populus tremuloides*), which proceeded towards an open parkland until about 10,100 years BP. A balsam fir-white birch domain can be proposed for the period from 10,100 to 7500 BP, after which the sugar maple-linden domain dominated until the present day. The Mount Shefford diagram is proposed as a standard-diagram because of the outstanding completeness of the pollen sequences, the oldest being contemporaneous with the Saint Narcisse frontal morainic system episode. Methodological aspects concerning the interpretation in terms of vegetation are discussed, and the main pollen assemblage zones of south-central Québec are presented.

A.A.

720. **RICHARD, P. 1980. Histoire postglaciaire de la végétation au sud du lac Abitibi, Ontario et Québec. Géographie physique et Quaternaire 34(1):77-94.**

Complete sequences of sediments representing the time since ice retreat (ca. 9,000 BP) and drainage of proglacial Lake Ojibway (ca. 7,900 BP) have been recovered from Lake Yelle and Lake Clo, two lakes, in a region about 10 km south of Lake Abitibi. The interpretation of the pollen diagrams leads to the reconstruction of an open forest dominated by black spruce (*Picea mariana*), with abundant aspen (*Populus tremuloides*) and jack pine (*Pinus divaricata*), at the southern shore of Lake Ojibway around 8,900 BP. This type of vegetation lasted about 1,000 years on the islands formed at that time by the hills around Lake Yelle, while Lake Ojibway's level fell from 355 to 280 m. The forest vegetation migrated rapidly into the lowlands after the drainage of the proglacial lake. From 7,900 to 7,200 years BP, the forest was a balsam fir - white birch community, on the mesic sites, but black spruce and jack pine were abundant. From 7,200 to 6,000 BP, the vegetation was at its maximum diversity and thermophily. White pine (*Pinus strobus*) migrated into the area, especially on hills and on xeric sites. Between 6,000 and 3,250 BP, juniper (*Juniperus*) became more abundant, the forest canopy being still open. Since 3,250 BP, the forest cover has closed and black spruce and jack pine have increased at the expense of white pine, in particular. The balsam fir-white birch community, on the mesic sites, has remained almost unchanged in the landscape and the vegetational evolution has been synchronous between the two sites since 7,900 BP.

A.A.

721. **RICHARD, P.J.H. 1981. Palaeoclimatic significance of the late-Pleistocene and Holocene pollen record in south-central Québec. In: Quaternary Paleoclimate. Edited by: W.C. Mahaney. Geo Abstracts, Norwich. pp. 335-360.**

-Our knowledge of the pollen record in lake and bog deposits of southern Québec has improved during the last decade. About 250 taxa are now identified, 125 to the specific level. Pollen assemblages consequently appear more complex, due also to the increasing number of sites analysed. The pollen record can be fitted into pollen zonations with different degrees of simplification, depending on the criteria used. These criteria lead to different degrees of paleoclimatic significance. Improving chronological control on the pollen zones shows metachronicity that also has a definite effect on the paleoclimatic significance of the results. The different approaches to paleoclimatic interpretation of the pollen data are reviewed for the southern Québec record. The thesis that climatic reconstruction must be made through an adequately detailed reconstruction of the vegetation is put forward. In this context, duration and competition are primary parameters to look at. These concepts, applied to the late glacial record of south-central Québec, allow the reconstruction of a paleoclimatic regionalism that differs essentially from the present-day pattern. There is also the need for regional climatic reconstructions to be made independently of any global continental or transcontinental scheme.

A.A.

722. RICHARD, P., and P. POULIN. 1976. Un diagramme pollinique au Mont des Eboulements, région de Charlevoix, Québec. Canadian Journal of Earth Sciences 13(1):145-156.

The history of vegetation has been registered in the sediments of Lake Mimi since about 11 000 BP. The initial vegetation traced is a tundra which, under severe climatic conditions, lasted for abut 1000 years. The herb tundra was progressively replaced by shrub tundra: a willow phase (*Salix*), followed by a dwarf birch phase (*Betula* cf. *glandulosa*) have been traced. These were followed by an afforestation phase characterized by an aspen community (*Populus tremuloides*) at about 10 000 BP. Spruce succeeded the aspen community, probably as an open black spruce (*Picea mariana*) community with some dwarf birch and green alder (*Alnus crispa*). An outstanding *Alnus* cf. *crispa* pollen peak (48%), supported by the annual pollen influx values, at the end of the spruce phase, could be interpreted as a return of colder climate that favoured the expansion of this shrub over forest. This event would date about 9750 BP. An open fir (*Abies balsamea*) forest followed, and changed to the balsam fir - white birch (*Betula papyrifera*) forest (climax domain), which prevailed until now. The richer sites supported sugar maple (*Acer saccharum*) - yellow birch (*Betula alleghaniensis*) community and fir-yellow birch stands since 6200 BP. Six radiocarbon dates and annual pollen influx values are offered, and some ecological problems related to the interpretation of the pollen diagram are discussed.

A.A.

723. RICHMOND, G.M. 1972. Appraisal of the future climate of the Holocene in the Rocky Mountains. Quaternary Research 2(3):315-322.

Consideration of the history of Holocene climate in the Rocky Montains indicates that the over-all trend during the past 2500 yr has been toward increasing warmth, interrupted by cooler times of minor advances of cirque glaciers. Comparison of Holocene climatic history with the record of past interglacials in the region suggests that the present interglacial is not complete and that the climate may become first warmer and subsequently wetter before it is completed. Correlation of the timing of the regional glacial-interglacial record for the past 140,000 yr with the record of major sea level changes and with the calculated changes in the earth's insolation suggest that the present interglacial may be completed within a few millenia and that it may be followed by a significant cooling of the climate.

A.A.

724. RITCHIE, J.C. 1964. Contributions to the Holocene paleoecology of westcentral Canada. I. The Riding Mountain area. Canadian Journal of Botany 42(2):181-196.

The results of pollen analysis of three sections of lake sediment, sampled in the Riding Mountain area of Manitoba, suggest a tentative division of each into four zones. The lower, interpreted as representing a closed white spruce forest, is followed by an apparently treeless episode tentatively interpreted as a grassland phase; this is followed by a zone which suggests indirectly the prevalence of deciduous forests, possibly dominated by poplar, birch, and oak. The development of the mixed boreal forest, which prevails today, is marked by a rise in the spruce and alder curves. The suggestion that the sections are post-Valders in age is corroborated to some extent by a carbon-14 age measurement of 9570 years from a sample of spruce wood excavated from the bottom of a filled-in kettle in the vicinity; associated gyttja yielded a pollen spectrum very similar to the I zones of the diagrams.

A.A.

725. RITCHIE, J.C. 1966. Aspects of the late-Pleistocene history of the Canadian flora. In: The Evolution of Canada's Flora. Edited by: R.L. Taylor and R.A. Ludwig. University of Toronto Press, Toronto. pp. 66-80.

[The author examines aspects of the late-Pleistocene history of the Western Interior of Canada. Findings from seven sites are used to suggest an interpretation of vegetation history.]

"Thus the late-Pleistocene history of the flora of the Western Interior of Canada will probably unfold ... as follows:

1. An initial, relatively rapid immigration from the south of a fairly rich, mixed, transcontinental flora following ice disintegration, made up of floral elements which later differentiated into low arctic, boreal, and temperate groups depending upon the particular reaction of their ecological amplitude with the changing environment.

2. An intrusion northward and eastward of a western plains flora into the areas which were forested in the late-glacial period. Only careful investigations in the future will reveal the exact extent of this early, post-glacial, grassland region.

3. A reappearance in southern Manitoba and Saskatchewan of deciduous forest elements, some migrating southward from the conifer forest to the immediate north (*Betula*) and others extending north and west from the eastern deciduous forests."

Excerpt+

726. RITCHIE, J.C. 1969. Absolute pollen frequencies and carbon-14 age of a section of Holocene lake sediment from the Riding Mountain area of Manitoba. Canadian Journal of Botany 47(9):1345-1349.

A section of Holocene lake sediment in the southern Boreal Forest of Manitoba was re-sampled and the sedimentation rate (0.039 cm per annum) calculated from eight carbon-14 age determinations. Pollen accumulation rates were computed, and an absolute pollen frequency diagram constructed. It suggests modifications of an earlier reconstruction of vegetation, based on relative pollen frequencies. A spruce-dominated assemblage occurred from about 11,500 to 10,000 BP, when there was a change to a treeless vegetation of a grassland type. This persisted until about 2500 BP, with the possible interpolation of an aspen parkland phase from 6500 to 2500 BP. The Boreal Forest in its present form (dominated by spruce, birch, and aspen, with local occurrences of pine, fir, larch, and oak) returned at 2500 BP, presumably in response to a deterioration in climate (cooler and (or) wetter).

A.A.

727. RITCHIE, J.C. 1972. Pollen analysis of late-Quaternary sediments from the Arctic treeline of the Mackenzie River Delta region, Northwest Territories, Canada. In: **Climatic Changes in Arctic Areas During the last Ten-Thousand Years. Edited** by: **Y. Vasari, H. Hyvärinen and S. Hicks. Acta Universitatis Ouluensis Series A, Scientiae Rerum Naturalium 3, Geologica 1:253-271.**

[The author presents the findings of four sections of lake sediments of late-Pleistocene age. The pollen stratigraphy of these four sites]..." is the basis of the following preliminary reconstruction of vegetation history for the Mackenzie Delta uplands in general:

Age B.P.	Vegetation
12,900-11,600	Tundra, dominated by dwarf birch, with open sites occupied by grass-*Artemisia* communities.
11,600-8,500	Invasion by spruce, forming a forest-tundra.
8,500-4,000	Development of a closed crown spruce forest with white birch. Alder invasion of the area about 5,500 B.P.
4,000-present	Retreat of spruce tree-line to present position; Tuktoyaktuk Peninsula, Richards Island and adjacent area occupied by shrub tundra with local abundance of alder.

Ritchie and Hare (1971) have outlined the climatological implications of these reconstructions in the following way. It is suggested that the palynological and megafossil evidence for an extension northward into the Tuktoyaktuk Peninsula of continuous spruce forest between 8,500 and 4,000 B.P. implies that the mean daily temperatures for the warmest months were about 5°C higher than at present and the growing season about 30 days longer. It is suggested that such an amelioration would require a displacement of the median July position of the Arctic front about 350 km north of its present position."

Excerpt$^+$

728. RITCHIE, J.C. 1976. The late-Quaternary vegetational history of the Western Interior of Canada. Canadian Journal of Botany 54(15):1793-1818.

The late-Wisconsinan pollen stratigraphy of the Western Interior of Canada is assembled and 16 representative sites provide a basis for establishing trends of vegetation history. Sites in the southern, prairie region show an early *Picea-Artemisia* assemblage ($12x10^3$ to $10x10^3$) replaced by a zone dominated by herb pollen. Similarly, sites in the Aspen Parkland and Transitional zones all have the *Picea-Artemisia* zone from as early as $13.9x10^3$ to $10x10^3$, followed by a herb zone. It is replaced by an arboreal pollen zone at $4.5x10^3$ to $3x10^3$ B.P. While there is a broad trend common to all sites in the modern boreal forest, from an early spruce-dominated assemblage to a late postglacial spruce-pine-birch assemblage identical with modern spectra, there are differences in the details of stratigraphy. Two sites in central Alberta have a poplar zone preceding the early spruce zone. Sites near the modern southern forest boundary show a late development ($3x10^3$B.P.) of the mixed boreal forest from prairie and hardwood deciduous forest communities. One site, at Flin Flon, Saskatchewan, provides clear evidence for a treeless episode (*Artemisia*-grass-sedge) preceding the spruce zone.

As the late-Wisconsinan glacial ended, an early version of the boreal forest, dominated by spruce and lacking pine, spread from adjacent U.S. onto deglaciated surfaces and till over stagnant ice. It persisted in the southern part of the area until about $10x10^3$ and until $6x10^3$ in the northernmost portions. In the south the spruce forest was replaced directly by prairie, spreading from the southwest and extending farther north than its modern limit between $7.5x10^3$ and $6x10^3$. All remnants of ice sheets and glacial lakes had disappeared by about $7x10^3$ and the northern part of the area was occupied by a boreal forest undergoing rapid changes in composition from the early spruce-dominated version to the mixed spruce-pine-birch poplar mosaic prevalent today. Pine probably spread from western refugia, at least into areas north and west of L. Winnipeg. At about $3x10^3$ the southern limit of the forest extended to the south, apparently in response to a climate with cooler and (or) wetter growing seasons. The rapid replacement of the spruce-dominated boreal forest by grasslands in the early postglacial was probably a response to warmer and drier growing seasons.

A.A.

729. RITCHIE, J.C. 1977. The modern and late Quaternary vegetation of the Campbell-Dolomite Uplands, near Inuvik, N.W.T., Canada. Ecological Monographs 47(4):401-423.

The Campbell-Dolomite Uplands comprise a small area (140 km^2) of outcropping, faulted dolomite, limestone, and shale east of the Mackenzie River Delta, ~40 km south of the northern limit of trees. The major landforms are bedrock ridges and plateaux, steep colluvium, stable slopes, shorelines, and depressions. A principal component analysis of vegetation-cover data from 150 stands suggests that much of the variation within the heterogeneous vegetation is correlated with these broad habitat categories. Stable surfaces bear an open spruce woodland with alder, tree and dwarf birch, and a varied lichen-heath-*Dryas* ground vegetation.

A glacially modified karstic (solution) depression contains a small (8 ha), relatively deep (22 m), apparently meromictic lake, which yielded a 12,000-yr core of sediment. A conventional percentage diagram, an influx diagram, and numerical analysis (principal components) suggest a sequence of pollen assemblage zones as follows: (1) *Salix*-Gramineae-*Artemisia*: 13,000 to 11,300 radiocarbon yr ago, (2) *Betula* (shrub)-*Salix*-Gramineae-*Artemisia*: 11,300 to 10,300, (3) *Betula-Populus*: 10,300 to 9,700, (4) *Betula-Populus-Juniperus*: 9,700 to 8,900, (5) *Picea-Betula* (tree and shrub)-*Juniperus*: 9,800 to 6,500, and, (6) *Picea-Betula-Alnus*: 6,500 to present. Both percentage data and numerical analyses show that none of the pollen assemblage zones 1 to 5 has a modern analogue.

With 1 exception, these patterns of change in pollen spectra can be interpreted parsimoniously without reference to regional environmental change. They suggest an initial phase of migration of willow and herbs from adjacent unglaciated Megaberingia (North Yukon and Alaska), followed rapidly by dwarf birch and poplar. Megaberingian floristic elements (e.g., *Plantago canescens, Selaginella sibirica*) reached the area during this early phase of migration. Subsequently arriving from the south along the Mackenzie valley were juniper, ericads, spruce, and finally alder, which intensified competition and restricted the early Megaberingian herb types to open, unstable habitats where they persist today. Slow soil development (humus accumulation, rising permafrost table) probably favoured the spread of the palynologically "silent" elements--lichens, ericads, and *Dryas* (the dominants of the modern ground vegetation). Changes in the influx values of *Picea* suggest a climatically induced increase in tree density and/or pollen production during the period 9,000-7,000 BP (Zone 5).

A.A.

730. RITCHIE, J.C. 1980. Towards a late-Quaternary paleoecology of the ice-free corridor. Canadian Journal of Anthropology 1(1):15-28.

The palaeoecology of the area known as the ice-free corridor is as poorly understood and documented as the geological evidence that there was in fact such an area. In the northern, Beringian portion the full-glacial (maximum 18,000 BP) was characterized by impoverished, tundra communities reflecting an environment colder, drier and less productive than during the Holocene and present-day. Most sites of greater apparent age (Middle Wisconsin), while they have yielded large numbers of vertebrate fossils, either lack stratigraphic context entirely or have stratigraphy of uncertain age and provenance. There is fragmentary evidence for Middle Wisconsin interstadial episodes that supported productive boreal woodland ecosystems.

A.A.

731. **RITCHIE, J.C. 1981. Problems of interpretation of the pollen stratigraphy of northwest North America. In: Quaternary Paleoclimate. Edited by: W.C. Mahaney. Geo Abstracts, Norwich. pp. 377-391.**

Pollen data from one site in the south Richardson Mountains of the Yukon Territory illustrate the limitations imposed by investigations in a region of great geological (bedrock) and topoclimatic diversity.

The paleoclimate model would suggest that the sequence of tundra-type herbs with additions of a willow element at 13,000 BP, dwarf birch at 12,500 and spruce at 10,000 or 11,000 BP reflects a change in climate from one similar to modern mid-arctic latitudes through low-arctic to subarctic or northern boreal over the 3 millennia involved, using the floristic-climatic zones proposed by Young (1971) as the modern analogue. Such a sequence is concordant with our general understanding of the nature of hemispheric climatic change from glacial to interglacial modes over the period 18,000 to 11,000 BP, although the data base for these reconstructions (e.g. CLIMAP 1976) in northwest North America is scant. On the other hand, the paleoclimatic sequence suggested by Delorme *et al.* (1977) for the same time and area, based on ostracod data interpreted by a modern-analogue numerical technique, is substantially at variance with the above interpretation. Clearly additional data are required.

A rival hypothesis to account for the spruce pattern is that it has migrated from southern refugia, down the Mackenzie valley, reaching western Alaska at roughly 6000 BP (Ritchie, 1979). In fact the available radiocarbon dates for the spruce rise at sites along the Mackenzie valley and westward into Alaska are still too few--and those available are not entirely sequential along this supposed migration route--to settle the issue of climatic change versus differential migration.

pA.A$^+$

732. **RITCHIE, J.C. 1982. The modern and late-Quaternary vegetation of the Doll Creek area, north Yukon, Canada. The New Phytologist 90:563-603.**

In addition to data on the modern vegetation in the Doll Creek area, northern Yukon Territory, the author provides detailed pollen analysis from Lateral Pond (where five radiocarbon dates provided geochronological control: 15,200 ± 230 years B.P. (GSC-2758); 14,800 ± 260 years B.P. (GSC-2785); 12,100 ± 130 years B.P. (GSC-2808); 7,510 ± 170 years B.P. (GSC-2852); 6,800 ± 80 years B.P. (GSC-2854)). Immediately following the peak of the last glaciation (about 18,000 B.P.) the area supported a sparse herb tundra on lower montane slopes and sedge-grass marsh in poorly-drained sites. Climate evidently was cold and harsh. Between 16,000 and 12,500 years B.P. willow, grass, sedge and herbs increased. By 12,500 years B.P. the region was occupied by treeless communities in response to a slow amelioration of climate. An abrupt warming occurred about 12,000 years B.P., coincident with the spread of dwarf shrubs (birch and ericads), and a gradual increase in spruce until the present status of woodland was reached about 7,500 years B.P. Alder and tree birch expanded to their modern status about 6,000 years B.P.

C.R.H.

733. **RITCHIE, J.C., J. CINQ-MARS, et L.C. CWYNAR. 1982. L'environnement tardiglaciaire du Yukon septentrional, Canada. Géographie physique et Quaternaire 36(1-2):241-250.**

Pollen analysis of sediments at Bluefish Caves site approximately 60 km southwest of Old Crow, Yukon Territory, shows two main pollen assemblages. The assemblage from the late Wisconsin (16,000 to 12,000 years B.P.) loess indicates the presence of relatively harsh climatic conditions with sparse herb tundra on the uplands and sedge-grass marshes on the lowlands. The overlying humus, as well as marking the end of the Pleistocene megafauna in the area, contains a pollen assemblage indicating a great increase in spruce and alder, and a rapid passage from the earlier cold, dry glacial climate to a warmer, moister climate.

C.R.H.

734. **RITCHIE, J.C., and B. DE VRIES. 1964. Contributions to the Holocene paleocology of westcentral Canada. A late-glacial deposit from the Missouri Coteau. Canadian Journal of Botany 42(6):677-692.**

A buried deposit of limnic sediment was excavated from a site on the Missouri Coteau of Saskatchewan, within the Mixed Prairie section of the Great Plains. Carbon-14 determinations indicate that the section is late-glacial, possibly deposited during an interstadial terminated by the Condie (=Valders?) re-advance. On the basis of the records of about 60 taxa of Tracheophyta and a pollen diagram, the section is characterized by lower, middle, and upper plant assemblages. It is suggested that the lower and upper assemblages, distinguished mainly by a *Picea-Shepherdia canadensis-Salix-Artemisia* pollen spectrum, indicate the prevalence on mesic sites of a spruce forest. The middle assemblage, having an array of macrofossils and a few microfossils of temperate geographical affinity and a pollen spectrum suggesting relatively less spruce and (or) more herbaceous vegetation, is interpreted in terms of a mixed spruce-poplar forest on mesic sites with shrub and grassland communities on the more xeric habitats. This tripartite division of the section in terms of ecologically concordant plant assemblages suggests an amelioration of environment followed by a deterioration which was probably correlative with the Condie re-advance.

A.A.

735. **RITCHIE, J.C., and K.A. HADDEN. 1975. Pollen stratigraphy of Holocene sediments from the Grand Rapids area, Manitoba, Canada. Review of Palaeobotany and Palynology 19(3):193-202.**

Two sections of sediment from a shallow lake on The Pas moraine gave a ^{14}C age of 7220 ± 110 years, a likely minimum age for the recession of Glacial Lake Agassiz II. Three pollen zones are recognized as follows: Zone 1, from 7300 to about 6200 BP, dominated by NAP (40-75%) with 6-22% spruce, 1-10% juniper and minor proportions of other trees, interpreted as a treeless vegetation, except for scattered spruce, dominated by juniper, grasses, sagebrush and herbs. Zone 2, from 6200 to 3500 BP, dominated by pine, with a mixed forest of poplar, pine and spruce. Zone 3, an assemblage occurring from 3500 BP to the present, consisting of spruce, pine and birch, representing the modern mixed boreal forest. These findings agree with archaeological data suggesting a shift from a plains to a woodland culture.

The climatic changes which we infer from this site are, that the area emerged from Glacial Lake Agassiz II about 7300 BP when the period of maximum post-glacial warmth and dryness was at its culmination; that about 6500 BP the climate deteriorated slowly, probably expressed as slightly cooler and less dry summers, causing a southward replacement of grassland and parkland by forest; and that a more rapid and marked deterioration occurred about 3500 BP.

A.A.+

736. **RITCHIE, J.C., and F.K. HARE. 1971. Late-Quaternary vegetation and climate near the Arctic tree line of northwestern North America. Quaternary Research 1(3):331-342.**

Earlier studies in Alaska and northwest Canada have shown inconsistent evidence for the expected northward extension of the Arctic tree line during the Hypsithermal Interval. Only megafossil evidence has supported this suggestion; the palynological findings have been inconclusive. The Tuktoyaktuk Peninsula, in the Northwest Territories of Canada, offers critical sites for studies of late-Pleistocene ecology, because of its geological, biotic, and climatological features. Palynological and megafossil evidence is presented from sites on the Tuktoyaktuk Peninsula, indicating northward advance of the Arctic tree line during the period 8500-5500 B.P. Relative pollen frequencies of a core of lake sediment suggest a late-Pleistocene sequence as follows: 12,900-11,600 dwarf birch tundra; 11,600-8500 forest tundra; 8500-5500 closed-crown spruce-birch forest; 5500-4000 tall shrub tundra; 4000 present dwarf birch heath tundra. These results suggest that during the Hypsithermal Interval the Arctic Front (July position) was further north, over the Beaufort Sea, a displacement from its present position of about 350 km. The Tuktoyaktuk Peninsula, presently occupied by tundra, and dominated by the Arctic airstream in July, was apparently under forest, with warm, moist Pacific air during the Hypsithermal Interval.

A.A.

737. RITCHIE, J.C., and L.K. KOIVO. 1975. Postglacial diatom stratigraphy in relation to the recession of Glacial Lake Agassiz. Quaternary Research 5(4):529-540.

The sediment and diatom stratigraphy of a small pond on The Pas moraine, near Grand Rapids, Manitoba, reveals a change in sedimentary environment related directly to the last stages of Glacial Lake Agassiz. Beach sands were replaced by clay 7300 ^{14}C y.a., then by organic silt and, at 4000 ^{14}C y.a. by coarse organic detritus; the corresponding diatom assemblages were (I) a predominantly planktonic spectrum in beach sands; (II) a rich assemblage of nonplanktonic forms, and (III) a distinctly nonplanktonic acidophilous spectrum. These results confirm Elson's (1967) reconstruction of the extent and chronology of the final (Pipun) stage of Glacial Lake Agassiz. The sedimentary environments change from a sandy beach of a large lake at 7300 BP to a small, eutrophic pond with clay and silt deposition from 7000 to 4000 BP. From 4000 BP to the present, organic detritus was deposited in a shallow pond that tended toward dystrophy.

A.A.

738. RITCHIE, J.C., and S. LICHTI-FEDEROVICH. 1967. Pollen dispersal phenomena in arctic-subarctic Canada. Review of Palaeobotany and Palynology 3:255-266.

The interpretation of sub-fossil spectra from Holocene deposits is hampered by certain unresolved problems in pollen analysis. One of these is the qualitative and quantitative significance of pollen transport by air movement, from one vegetation region to another. An automatic volumetric pollen-spore trap was used at a subarctic, forest-tundra station to examine daily pollen spectra from the atmosphere. The results show instances of long-distance dispersal of pollen of anemophilous tree species confined to temperate North America. Further, it provides a detailed atmospheric spectrum for a subarctic site. Cumulative samples from high-, low- and mid-Arctic stations reveal further the extent of long-distance transport of tree pollen, and the nature of contemporary Arctic spectra.

A.A.

739. RITCHIE, J.C., and S. LICHTI-FEDEROVICH. 1968. Holocene pollen assemblages from the Tiger Hills, Manitoba. Canadian Journal of Earth Sciences 5(4, part 1):873-880.

Coring of three kettle lakes in the moraine area known as the Tiger Hills, Manitoba, yielded sections of sediment which span the Holocene for this region. Detailed pollen analysis of two of the sections suggests five main pollen assemblage zones for the Holocene, numbered I to V from above. Zone V is interpreted as a spruce-dominated vegetation associated with such pioneering species as *Shepherdia canadensis* and *Artemisia*, a type found at present as local fragments and having no regional equivalent. Zone IV also has no analogue among recent pollen spectra, and is interpreted as a mosaic of mixed coniferous - broadleaved deciduous forest stands, and extensive scrub with *Juniperus* and grassland. Zone III is dominated by non-arboreal pollen types and suggests grassland, while Zone II has an oak component, which indicates a savanna type. Zone I is the modern assemblage, with prominent representation by weedy species. Radiocarbon age determinations suggest that the area was occupied by the Zone V assemblage from about 12 800 B.P.

A.A.

740. **RITCHIE, J.C., and G.A. YARRANTON. 1978. The late-Quaternary history of the boreal forest of central Canada, based on pollen stratigraphy and principal components analysis. Journal of Ecology 66(1):199-212.**

(1) Pollen stratigraphic data from four ^{14}C-dated sections of Holocene sediment at sites in the boreal forest region of central Canada were analysed by standard relative frequency pollen diagrams and by principal components analysis (PCA). Ordination of the 173 pollen samples on the second and third components of the PCA facilitated comparison between zones and sites.

(2) Modern pollen samples from 110 sites throughout the modern vegetation zones of the Western Interior of Canada were ordinated onto the same principal component axes as the subfossil data, to provide a further comparative, graphical description of the data.

(3) The two northern sites revealed a stratigraphic sequence from a treeless *Artemisia*-willow-sedge zone, through a *Picea-Juniperus-Artemisia* zone, to zones dominated by mixtures of pine, spruce, birch and alder.

(4) At the two southern sites, by contrast, an early treeless zone was lacking; there were comparable early spruce and final mixed-forest zones, but the intermediate zones were dominated by herb and non-coniferous tree types.

A.S.

741. **ROBERTS, A. 1981. Holocene environmental inferences from southern Ontario Paleo Indian and Archaic archaeological site locations: *c*. 11,000 to 2,500 years BP. In: Quaternary Paleoclimate. Edited by: W.C. Mahaney. Geo Abstracts, Norwich. pp. 411-421.**

The location of a fluted projectile point in an area that is believed to have been glaciated c. 11,500 to 11,200 yrs. BP is consistent with the scanty geological evidence and verifies that the Kirkfield outlet was probably deglaciated c. 11,200 yrs. BP.

Until recently, work on southern Ontario Archaic has been limited to a small number of comparatively well preserved sites. This gave an impression of a relatively extensive Laurentian Archaic occupation with suggestions of some later Archaic and Paleo Indian occupations. Surveys along the north shore of Lake Ontario show Archaic occupations similar to those recently defined in southwestern Ontario. These results support an Early Archaic "Carolinian" occupation, probably developing out of the preceding Paleo Indian phases. Data show a respectable correlation between Early and Middle Archaic site locations and the developing mixed hardwood forest during the period of climatic improvement from c. 9000 to 5000 yrs. BP. This evidence adds further support to the pollen and Coleoptera records for postglacial climatic change in southern Ontario.

A significant orientation along the north shore of Lake Ontario has been found for the Paleo Indian, Early Archaic and Middle Archaic sites. There is an avoidance of the kame moraine and lacustrine deposit areas north of the Oak Ridges Moraine until lake Archaic and Woodland time (c. 4000 to 600 yrs. BP). This pattern can be explained by two hypotheses: 1. increasing population pressure; and 2. variations in carrying capacity as a result of climate change. Greater diversity in Archaic adaptations and inferred larger population may have resulted in resource exploitation in more marginal areas. Evidence for the termination of the Thermal Maximum coincides with an increasing use of these areas leading to a higher carrying capacity and, hence, an increased exploitable resource.

A.A.

742. ROBIN, G. de Q. 1981. Climate into ice: the isotopic record in polar ice sheets. In: Sea Level, Ice, and Climatic Change. Edited by: I. Allison. International Association of Hydrological Sciences Publication 131:207-216.

A brief survey of processes that control isotopic δ values on polar ice sheets is given along with a summary of various studies of the relationship between mean δ values and mean temperatures. It is concluded that the error of temperature changes deduced from a mean δ value of an ice sample deposited over N years will be around $(0.7\sigma\delta^2/N)^{\frac{1}{2}}$, that is around +0.1°C for a 100 year mean. Empirical time-series studies of mean δ values and mean temperatures indicate that a ratio of $d\delta/d\theta$ of between 0.5 and 1.0 fits most data on a time scale ranging from seasonal variations to millenia. However ice core data cannot be used to infer past climatic fluctuations of temperature until allowance has been made for the flow of ice to the drilling site, including allowance for changes of ice sheet dimensions over the period involved. Data from two Antarctic ice cores appear consistent with the concept that isotopic profiles indicate changes over wide areas with errors of the expected magnitude. [Mentions Canada and considers Present and 18,000 BP polar regions.]

A.A.$^{+}$

743. ROE, F.G. 1954. The Alberta wet cycle of 1899-1903: a climatic interlude. Agricultural History 28(3):112-120.

Near Lacombe in south central Alberta, 1899 was a warm year with an abundance of rain in August, September and October. For the next four years a succession of similar conditions occurred with the wet season beginning a month earlier each year. In winter, the soil became a solid block of ice six to seven feet deep. By 1903 water levels were beginning to fall, but the entire country was like a swamp. In 1904 the snow cover cleared in April and a normal splendid season followed which broke the wet cycle. During the wet years there were no mosquitoes, the roads were terrible, and a re-survey of many road allowances was carried out to place the roads on ridges. The wet cycle also affected the much drier areas of southern Alberta.

At Lacombe, a clump of white poplar trees was killed by water after three years of the wet spell. The trees were 70 years old, implying that no such wet cycle had occurred since 1830. The author theorizes that evaporation has become greater as more of the Prairies have gone under cultivation. The year 1915 was the year with peak water levels, and since dessication is progressive, later years with heavy rains have never brought the water levels so high again.

Thomas

744. ROED, M.A. 1979. Origin of linear moraine and stagnation of the Laurentide Glacier in parts of Ontario. Geological Association of Canada-Mineralogical Association of Canada Joint Annual Meeting, Program and Abstracts 4:75.

Reconnaissance field work in northwestern Ontario and near Ottawa has resulted in the recognition of certain common stratigraphic features of major linear moraines. The interpretation presented indicates that the moraines formed in ice-walled channels and/or tunnels which developed along major structural zones of weakness in the stagnating Laurentide Glacier. Some of the linear moraines are in excess of 300 km in length and rarely exceed 1 km in width. Meltwater flowing along them may have been under considerable hydrostatic head in places. Later, as disintegration proceeded, most of the tunnels melted and collapsed and turned into ice-walled lakes that served to level the tops of these features. At Ottawa the Champlain Sea invaded the region when there was still ice-cored debris along some of the ice-walled channels, so that fossiliferous till was deposited, considered by some to represent a younger and separate glacial advance.

The linear moraine features have been considered to represent frontal moraines of a receding ice-sheet, and the ideas presented here suggest that a major revision of this concept and other deglaciation concepts is warranted in eastern Canada.

A.A.

745. **RUDDIMAN, W.F., and L.K. GLOVER. 1975. Subpolar North Atlantic circulation at 9300 yr BP: faunal evidence. Quaternary Research 5(3):361-389.**

We have examined the circulation of the subpolar North Atlantic at 9300 yr BP by using a dispersed layer of silicic volcanic ash as a synchronous horizon. At the level of this datum, we have reconstructed from foraminiferal evidence a geologically synoptic view of seasonal variations in sea-surface temperatures and salinities. The reconstruction defines two oceanic fronts at 9300 yr BP: (1) The meridionally oriented Polar Front bordering the axis of deglacial outflow of Arctic and Laurentide ice and meltwater and (2) a zonal portion of the Subarctic Convergence along 48°N, marking a major confluence between the subtropical and subpolar gyres. The 9300-yr configuration primarily differed from the modern pattern in the more easterly position (by 3°) of the Polar Front and the more southerly (3°) and easterly (5°) position of the Subarctic Convergence. Both fronts had been merged at 18,000 yr BP into the full glacial Polar Front; 9300 yr BP, they were approaching the end of a northwestward deglacial retreat toward the modern interglacial positions.

There were two dominant departures at 9300 yr BP from the Earth's modern configuration, both related to deglaciation: the very large Laurentide Ice Sheet still covering eastern North America to 48°N, and the region of cold Arctic/Laurentide deglacial outflow. These two features caused: a more easterly position than now of the region of upper air divergence and lower air convergence downstream from the Ice Sheet and meltwater outflow; a more intense expression of this upper air divergence and lower air convergence over the central portion of the subpolar North Atlantic; and a latitudinally more stable axis of convergence of surface westerlies over this region. These factors apparently caused the stronger oceanic convergence along 48°N than at present. They also created a stronger, southeastward-directed wind drift current, which opposed the meridional (northward) flow typical of the present interglaciation.

A.A.

746. **RUDDIMAN, W.F., and A. McINTYRE. 1979. Warmth of the subpolar North Atlantic Ocean during Northern Hemisphere ice-sheet growth. Science 204(4389):173-175.**

Two 10,000-year periods of Northern Hemisphere continental ice-sheet growth stand out prominently within the last full interglacial-to-glacial cycle. During the first half of each rapid ice-growth phase, the subpolar North Atlantic from 40°N to 60°N maintained warm sea-surface temperatures comparable to those of today's ocean. The juxtaposition at latitudes 50°N to 60°N of an "interglacial" ocean alongside a "glacial" land mass, particularly along eastern North America, is regarded as an optimal configuration for delivering moisture to the growing ice sheets.

A.A.

747. **RUDDIMAN, W.F., and A. McINTYRE. 1981. The North Atlantic Ocean during the last deglaciation. Palaeogeography, Palaeoclimatology, Palaeoecology 35:145-214.**

The last deglacial warming of the high-latitude North Atlantic Ocean (40°-65°) occurred in three discrete steps: in the southeast and central regions at 13,000 BP; in the central and northern sectors at 10,000 BP; and in the western (Labrador Sea) sector between 9,000 and 6,000 BP. This regionally time-transgressive sequence was punctuated by a major cooling and polar front readvance from 11,000 to 10,000 BP; this briefly returned most of the high-latitude North Atlantic to almost full-glacial temperatures.

Carbonate productivity levels reached minimum values from 16,000 BP to 13,000 BP and then gradually rose, reaching maximum values in the Holocene at about 6,000 BP. We interpret these changes in carbonate productivity as indicating a major influx of products of glacial wastage (meltwater and icebergs) from 16,000 to 13,000 BP, with considerably reduced influx after 13,000 BP. Combined with evidence for meltwater to the Gulf of Mexico via the Mississippi River, this suggests that the bulk of volumetric deglaciation in the Northern Hemisphere occurred considerably earlier than the main areal retreat of ice-sheet limits.

This implies that the still-extensive ice sheets in the Northern Hemisphere were relatively thin by 13,000 BP. Because there is no palynologic evidence of unusual atmospheric warming on the southern margins of the ice sheets before 13,000 BP, we infer that this early phase of rapid ice disintegration occurred largely by iceberg calving and marine downdraw.

We also infer that from 16,000 to 13,000 BP low winter insolation combined with a low-salinity meltwater layer to form sea ice south to 50°N; after that date, the winter sea-ice cover diminished significantly. We infer from this that the critical flux of winter moisture to the ice sheets was largely cut off from 16,000 to 13,000 BP and still significantly suppressed after 13,000 BP. Moisture starvation thus hastened the disintegration of Northern Hemisphere ice masses.

The brief but strong ocean cooling roughly coincident with the European Younger Dryas (11,000 to 10,000 BP) appears to mark a major influx of tabular icebergs from a disintegrating Arctic ice shelf, perhaps enhanced by external forcing at higher frequencies (2,500 yr).

A.A.

748. RUTTER, N.W. 1969. Pleistocene paleosol investigations in parts of Western Canada. In: Pedology and Quaternary Research. Edited by: S. Pawluk. University of Alberta Press, Edmonton. pp. 83-102.

Very few Pleistocene paleosols have been described in Western Canada and these are confined mostly to buried soils. Three areas are discussed that offer promise for relict paleosol study at the present time -- the Interior Plains, the Rocky Mountains and environs, and parts of the Yukon. Reconstruction of past geomorphology, climate and vegetation, and time relationships may be aided by comparing soils on different surfaces and by individual study.

In the Interior Plains, stillstands and readvances of the last glaciation may be detected by recording differences in weathering intensity and profile thicknesses of soil in till on either side of a former ice front position. In the southern Rocky Mountains and environs three surfaces of widely varying age are present -- at lower elevations, Wisconsin; at intermediate elevations, pre-Wisconsin (?); and at higher elevations, unglaciated surfaces. By relict soil study it may be possible to confirm that the pre-Wisconsin (?) surface actually represents an interglacial interval. In parts of the Yukon, at least four distinct surfaces are present. These include a non-glacial surface, at least Miocene age: a high terrace, whose surface dates from pre-Illinoian time, and lower terraces dating from early Wisconsin or Illinoian and late Wisconsin times. The presence of ancient surfaces at varying elevations permits detailed study of the complexities and inter-relationships of soil development and geomorphic evolution.

A.A.

749. RUTTER, N.W. 1980. Late Pleistocene history of the western Canadian ice-free corridor. Canadian Journal of Anthropology 1(1):1-8.

Recent investigations of the relationship between Pleistocene Cordilleran and Laurentide glaciers suggest that the ice-free corridor was closed for a relatively short period during Wisconsin Glaciation. The corridor could have been closed sometime during Early Wisconsin (approximately 100,000-120,000 to approximately 50-70,000 years BP) although little is known about glacial events during this period. It was most likely open during the Middle Wisconsin. During Late Wisconsin time (approximately 10,000 to 25,000 years BP) the corridor was probably open from about the U.S.-Canadian border to the Jasper-Edmonton area, closed for a period from the Jasper-Edmonton area northward to the B.C.-Alberta border and open beyond to the Arctic Ocean. Man could have migrated freely in this region during most of the Wisconsin.

A.A.

750. SAARNISTO, M. 1974. **The deglaciation history of the Lake Superior region and its climatic implications. Quaternary Research 4(3):316-339.**

A zone of synchronous end moraines has been recognized in the Lake Superior region across northern Ontario and Michigan. The moraines were formed between 11,000 and 10,100 y.a. as cold climate resulted in successive halts in the general ice retreat. The cold climate is also indicated by the presence of tundra near Lake Superior until about 10,000 y.a. This episode is here referred to as the Algonquin Stadial. It was preceded and followed by rapid deglaciation. The Algonquin Stadial is comparable in age with the Younger Dryas Stadial of Europe, and indicates a reversal in the continuous trend toward a warmer climate during Late-Wisconsin(an) time. The apparent conflict between the present result (based on geologic evidence) and earlier pollen stratigraphical studies with no reversal is discussed.

Glacial Lake Duluth formed in the western Lake Superior basin before 11,000 BP, followed by a series of Post-Duluth lakes between approximately 11,000 and over 10,100 BP. The Main Lake Algonquin stage in the Huron and Michigan basins terminated approximately 11,000 BP. The subsequent high-level post-Main Algonquin lakes, which were contemporaneous with the Post-Duluth lakes, existed in the southeastern Lake Superior basin. When the ice margin was along the north shore 9500 BP Lake Minong occupied the whole Lake Superior basin. By 9000 BP the ice had retreated north of Lake Superior-Hudson Bay divide.

A.A.

751. SABO, G., III, and J.D. JACOBS. 1980. **Aspects of Thule culture adaptations in southern Baffin Island. Arctic 33(3):487-504.**

An archaeological sequence of Neo-Eskimo occupations, based upon excavations of eight Thule winter houses near Lake Harbour, Baffin Island, is outlined, beginning around A.D. 1100 and extending into the present century. Relationships between past climatic events, local environmental characteristics, and the organization of Neo-Eskimo subsistence-settlement systems are traced throughout this period of time, based on analysis of artifactual, faunal, and midden deposit data. A rescheduling of procurement systems, coupled with a shift in the emphasis of fall/winter settlement options, is seen in response to climatic/ecological changes, commencing after A.D. 1250, which affected the accessibility of bowhead whales, ringed seal, and caribou. It is suggested that flexibility in the organization of domestic units and demographic arrangements was an important cultural mechanism permitting Thule and recent Inuit populations to respond effectively to changes in their biophysical environments.

A.A.

752. SACHS, H.M. 1975. **Radiolarian-based estimate of north Pacific summer sea-surface temperature regime during the latest glacial maximum. In: Climate of the Arctic. Edited by: G. Weller and S.A. Bowling. 24th Alaskan Science Conference, University of Alaska, Fairbanks. pp. 37-42.**

Objective quantitative estimates of paleo-oceanographic conditions in the Subarctic Pacific can be made by analyses of radiolarian assemblages. By appropriate computations, transfer functions developed in a study of surface sediments can be used to estimate oceanographic conditions in deep-sea cores containing late Pleistocene faunas. For this study, two core traverses (at about 166°E and 165°W, between 35° and 50°N) were examined. Glacial maximum conditions were taken as the most recent temperature minima encountered. (More precise age control is not yet feasible in these slow deposition-rate, carbonate-free cores). The results indicate that parts of the North Pacific were significantly colder than today (by about 4-5°C at 45°N), and can be used to reconstruct oceanographic conditions during this time interval.

A.A.

753. SAVOIE, L., et P. GANGLOFF. 1980. Analyse pollinique d'une palse au site archéologique de Vieux-Port-Burwell (Killiniq), Territoires du Nord-Ouest. Géographie physique et Quaternaire 34(3):301-320.

Two pollen diagrams, one located at the summit (A) and the other at the foot (B) of a palsa, 3m from each other, reflect the geomorphological evolution of the site in a fen at Killiniq. Between 5000 and 580 BP, the same evolution is registered by the two diagrams, i.e., the progressive development of the fen. The pollinic zonations which mark this period of time are imputed to paleoclimatic variations. The important low in local pollen representation which appears around 3700 BP shows that difficult conditions for plant growth prevailed at that time. Around 2430 BP a break in pollinic zonations IV and III correlates in diagram C, taken at 300 m from the studied site, to the outcome of minerotrophic peat, which probably points to an aggradation of the permafrost. Temperatures begin to get warmer around 1430 BP. Starting from 580 BP, a divergent evolution is recorded by the two pollen diagrams. Peat grows faster in B. Peat ceases to grow, dires and packs in A. Gramineae pollen takes up high percentages in the assemblages. All these events are due to the growth of a palsa in the fen. This palsa dates back to 600 years. It is more the result of progressive thickening of the peat to a point permitting the formation of a palsa than a climatic oscillation.

A.A.

754. SCHAFER, C.T., and J.N. SMITH. 1979. Sedimentation at the head of the Saguenay Fjord. Geological Association of Canada-Mineralogical Association of Canada, Joint Annual Meeting, Program and Abstracts 4:76.

Unbioturbated marine sediments containing a record of high river discharge events occur at the head of the Saguenay Fjord, near Saint Fulgence. Preservation of allochthonous benthonic foraminifera fossils, recognition of occasional rapid sedimentation events associated with the spring runoff of the Saguenay River, and the unmixed character of the sediment, can be used in conjunction with several dating techniques to obtain a temporal resolution of paleoriverine events on a time scale of months to years.

The geologic and geochemical record of the upper 150 cm of sediment reflects (1) the anoxic character of the benthic environment due to the high flux of terrigeneous material to the bottom; (2) the transport and deposition of landslide-derived sediment into the head of the Fjord over several years; (3) an indication of the nature and timing of dissolution processes that have reduced, or totally eliminated the allochthonous calcareous microfossil assemblage from the recycled sediment; (4) a cyclic depositional pattern that may be useful in reconstructing paleoclimatological trends that have caused variations in annual river discharge over the past millennium.

A.A.

755. SCHAFER, C.T., and F.J.E. WAGNER. 1978. Foraminifera-mollusc associations in eastern Chaleur Bay. Canadian Journal of Earth Sciences 15(6):889-901.

Common associations of mollusc and Foraminifera species were investigated in eastern Chaleur Bay, Gulf of St. Lawrence. Three depth-related biotopes are recognized. The distribution of species in this open bay environment appears to be controlled by substrate and (or) water mass characteristics. North-south differences in shallow water assemblages are related to summer bottom water temperature; calcareous Foraminifera and molluscs dominate in relatively high temperature environments. The influx of cold water (<1°C) at intermediate depths (40-80 m) is reflected by an increase in the abundance of arenaceous Foraminifera species such as

Reophax scottii, and by the absence of numerous mollusc species that are found at these depths elsewhere. A deep bay biotope (>80 m) can be recognized primarily on the basis of the mollusc species *Yoldia limatula* and *Periploma fragile* in association with the Foraminifera species *Islandiella islandica*. The observed mollusc-Foraminifera associations can be applied to paleoenvironmental and biostratigraphic studies of north temperate Holocene marine sediments.

A.A.

756. **SCHELL, I.I. 1961. Recent evidence about the nature of climatic changes and its implications.** Annals **of the New York Academy of Sciences 95(1):251-270.**

Attempts to reconcile, in the case of the ice age, the seeming paradox of a steeper equator-to-pole temperature gradient, increased circulation, evaporation and precipitation, with a decreased solar output that apparently calls for opposite conditions. Essential requirements for an ice age are exemplified by three theoretical cases, which would produce very much lower temperatures at the poles, a steeper equator-to-pole temperature gradient, greatly increased circulation and evaporation, and greater precipitation except over the ice areas. Three actual cases illustrate the significance of temperature changes; one for a short period 1901-20 to 1921-40, one for a long period from a glacial to an interglacial, and one for the 1851-1900 to 1901-50 period for a limited area based on 165 selected station records. General effects expected from increasing and decreasing solar output are discussed and compared with the evidence concerning climatic changes from a glacial to an interglacial. High-latitude decrease in temperature and greater precipitation near the ice edge took place during the glacial; temperatures, precipitation and evaporation followed opposite trends in the interglacial. Lake of ice in northernmost Greenland and Canada is explained by lack of precipitation and rapid evaporation. Further warming is indicated, with possibly one or more severe coolings and other less severe coolings before the end of this interglacial.

A.B.

757. **SCHELL, I.I. 1962. On the iceberg severity off Newfoundland and its prediction. Journal of Glaciology 4(32):161-172.**

Analysis of the iceberg count off Newfoundland for 1880-1925 shows that stronger than usual NW winds off the Labrador and Newfoundland coasts and relatively low temperatures over Newfoundland during December-March lead to greater than average berg counts off Newfoundland in April-June. Conversely, lighter NW winds and higher temperatures lead to lower berg counts in the following months. The relative strength of winds can be measured by the pressure difference between Belle Isle and Ivigtut. The relationship investigated provides a basis for predicting the berg count each year at the end of March, and computed values compared with actual values on scale 0 to 10 for the following period in 1927-1961 show marked agreement. A more detailed representation of wind, temperature and other elements during the winter and early spring in the area would lead to a closer relationship with the berg count and a broader basis for its prediction.

A.B.

758. **SCHELL, I.I., D.A. CORKUM, and E.N. SABBAGH. 1975. Recent climatic changes in the eastern North American sub-Arctic. In: Climate of the Arctic. Edited by: G. Weller and S.A. Bowling. 24th Alaskan Science Conference, University of Alaska, Fairbanks. pp. 76-81.**

An analysis of the iceberg count, mainly April-June months, off Newfoundland during the period 1921-1970 showed a sharp decrease in the number of bergs crossing 48°N, from an average of 435 bergs per year in the 1921-50 period (470, 419, 418 respectively in the first, second and third decades) to 240 in the 1951-60 and to 150 in the 1961-70 decades. The decrease was associated with a decrease in the strength of the December-February northwesterly winds along the Labrador and Newfoundland coasts as measured by the pressure differences between 50°N, 60°W and 60°N, 50°W... and also a decrease in the winds further north, causing fewer bergs to drift southward with the Labrador current. It was also associated with a more northeasterly direction of the April winds in the 1961-70 decade than in the preceding 1951-60 decade and with a still greater northeasterly direction than in the 1921-50 period, allowing for a greater proportion of the reduced numbers of bergs to drift southwestward, there to be grounded in the bays and shallows along the coasts. The decrease in bergs was further associated with an increase in the December-February air temperatures at St. John's (Torbay), Newfoundland from -3.6°C to -2.1°C between the 1920/1-1949/0 and 1950/1-1959/0 periods, and a further increase of 0.2°C in the 1960/1-1969/0 decade over the 1950/1-1959/0 decade. The low berg count in the 1961-70 decade was followed in 1972 by the heaviest count on record (1590 bergs) and by another heavy count in excess of 800, or more than twice the long-term average, in 1973.

Also, the sharp decrease in icebergs in the 1961-70 decade was associated with a marked ice season extending into September in Baffin Bay, showing that the climatic elements in this decade underwent different changes in each of the regions in accordance with Faegri's law: the shorter the period of climatic change, the smaller the area similarly affected.

A.A.

759. SCHOFIELD, W.G., and H. ROBINSON. 1960. Late-glacial and postglacial plant macrofossils from Gillis Lake, Richmond County, Nova Scotia. American Journal of Science 258(7):518-523.

An analysis of plant macrofossils in a deposit from Gillis Lake, Richmond County, Nova Scotia is compared with the pollen analysis from the same deposit. The macrofossils belong to aquatic or lake-shore genera or to trees with windborne seeds. Zones containing a variety of macrofossils from aquatic plants and lacking those from lake-margin species in other zones are interpreted to reflect a drier climate. Of the two birch species represented, a larger number or exclusive presence of *Betula lutea* seeds suggests a milder climate, whereas a larger representation of *B. papyrifera* suggests cooler conditions. Using these criteria, the macrofossil record largely supports the conclusions made from the pollen analysis. The water milfoil *Myriophyllum heterophyllum* is identified from fossil seeds. This species is presumably extinct in the present flora of Nova Scotia.

A.A.

760. SCHROEDER, J. 1977. Les formes de glaces des grottes de la Nahanni, Territoires du Nord-Ouest, Canada. Canadian Journal of Earth Sciences 14(5):1179-1185.

Exploration has been continuing on the karst system developed within the cliffs of the First Canyon (300-1050 m deep) of the South Nahanni River (61°18'N, 124°10'W). Probably the most northerly on the North American continent, this karst region is within the discontinuous permafrost zone, at the southern limit of the tundra. The caves contain ice of the type which depends on the present subarctic climate (two-dimensional hexagonal ice crystals, ice-like calcite speleothem and 'secondary' ice), or on a long-term climatic change of ± 2400 years (massive ice deposits and sponge-like deposits).

A.A.

761. SCHROEDER, R.A. 1974. Kinetics, mechanism and geochemical applications of amino acid racemization of various fossils. Ph.D. thesis, University of California, San Diego, 160 pp. Dissertation Abstracts International 35(10):4944B-4945B.

A new technique for geochronology and paleotemperature studies based on the chemical racemization of amino acids has been developed recently. It is based on the fact that living organisms contain, almost entirely, only L-amino acids; and, following death of the organism, racemization of the remnant amino acids gradually increases the proportion of D-enantiomers present (equal amounts of the D- and L-enantiomers at equilibrium). Equilibrium will be attained for amino acids contained within uncontaminated skeletal fossils after ∿ 10 m.y. at 0°C (typical deep-sea temperatures) and after a few hundred thousand years at 20°C (typical average tropical and temperate continental temperatures); although reliable dating does not presently extend to these limits.

The base of a core taken from Lake Ontario has been dated by both radiocarbon and aspartic acid racemization methods at ∿ 20,000 years BP and changes in amino acid concentrations, and profiles have been found to be distinguishing characteristics of the postglacial vs. glacial sediment. Racemization studies on argillaceous marine abyssal sediments were not successful, however, because bacterial decomposition had substantially reduced total amino acid concentration. However, important criteria for the absence of bacterial contamination in foraminiferal shells, and by implication in other fossils, are established from these results.

Because the racemization reaction is temperature dependent, the average temperature to which a fossil has been exposed since its deposition can be calculated, provided the age of the fossil is known by some independent means.

pD.A.I.

762. SCHULMAN, E. 1947. Dendrochronologies in southwestern Canada. Tree-ring Bulletin 13(2-3):10-24.

Sampling was carried out in southern interior British Columbia and at Banff National Park in Alberta. The growth of eight groups of cross-dateable trees in southwestern Canada was plotted. There is a strong tendency for persistence in ring chronology along the entire dry belt in south central British Columbia, but the chronology at Banff is substantially different. It is suggested that rainfall is the controlling element in growth. Lists of tree-ring indices in percent of the general trend of the growth are shown along with graphs indicating tree growth as an index of rainfall and temperature.

Thomas

763. SCHWARZBACH, M. 1963. Climates of the Past: An Introduction to Paleoclimatology. (Translated and edited by R.O. Muir), Van Nostrand, London. 329 pp.

A general textbook, which deals with the climatic history of the earth over the last thousand million years. One chapter is devoted solely to the Quaternary.

A.B.S.

764. SCHWARZBACH, M. 1963. The geological knowledge of the North Atlantic climates of the past. In: North Atlantic Biota and Their History. Edited by: A. and D. Löve. Pergamon Press, Oxford. pp. 11-19.

Outlines the climatic history of the area. Precambrian, Eocambrian, Paleo- and Mesozoic, Tertiary, and Quaternary climate are analyzed. Precambrian and Eocambrian are relatively little known; the Paleozoic and Mesozoic eras afford more information on Europe and North America, Greenland and Spitsbergen, through the floras, faunas, limestones and evaporites. Still better known are the climatic changes in the Tertiary and Quaternary. A summary is given. Successions of glacial and inter-glacial periods, ice-free refugia during glacial times, and possible Quaternary land bridges are briefly discussed.

A.B.

765. SCHWEGER, C. 1978. Use of lake sediments for reconstructing prehistoric fire records. In: Fire Ecology in Resource Management Workshop Proceedings, December 6-7, 1977. Edited by: D.E. Dube. Canadian Forestry Service Information Report NOR-X-210, Edmonton. pp. 30-33.

The author reviews the use of pollen analysis of lake and bog sediment cores to yield information which will permit reconstruction of prehistoric fire records. He discusses interpretive problems and provides examples from several Canadian locations.

"The Hypsithermal, a mid-Holocene (7000 to 4000 years ago) period of hotter and/or drier climate, is evidenced by higher charcoal frequencies at Lost Trail Pass Bog. But twice as much pollen was deposited during the past 2000 years, a period often called the Neoglacial, noted for its generally cooler and more moist climate. Because explanations involving natural agencies seem inadequate, it was suggested that aboriginal hunting patterns may have been responsible. Pollen studies done in central Alberta also demonstrate greater fire frequencies during the mid-Holocene when grasslands spread northward into the parkland and boreal forest."

A.B.S.

766. SCHWEGER, C.E., and J.A.P. JANSSENS. 1980. Paleoecology of the Boutellier nonglacial interval, St. Elias Mountains, Yukon Territory, Canada. Arctic and Alpine Research 12(3):309-317.

Alluvial, organic-rich sediments associated with the mid-Wisconsin Boutellier nonglacial interval (38,000 to 30,000 BP), St. Elias Mountains, Yukon Territory, yielded fossil pollen and bryophytes. Twenty-five pollen taxa were identified; Cyperaceae, Gramineae, and *Artemisia* dominated the pollen assemblages. Arboreal pollen was rare, while *Salix* was the only common shrub. Of the fossil bryophytes, *Drepanocladus brevifolius* was the most common; *Calliergon giganteum* and *Scorpidium scorpiodes* were less frequent and less well preserved.

The pollen record suggests a tundra meadow-tundra steppe mosaic with local willow groves. The bryophytes indicate an unweathered minerotrophic substrate. Comparisons with other dated mid-Wisconsin pollen localities of Alaska and Yukon suggest that the Boutellier pollen samples represent the upper zone of an altitudinal vegetational sequence similar to that of the present, but displaced downslope.

A.A.

767. Sea Level, Ice, and Climatic Change. Proceedings of the symposium held 7-8 December 1979 during the 17th General Assembly of the International Union of Geodesy and Geophysics, Canberra. Edited by: I. Allison. International Association of Hydrological Sciences Publication 131:1-471. 1981.

The major objective of the symposium was to review current ideas and recent results on the processes and the effects of interactions between sea level, ice, and climatic change on time scales of 100 to 10,000,000 years. [Papers relevant to this bibliography have been individually annotated.]

Editor+

768. SHARP, R.P. 1951. Glacial history of Wolf Creek, St. Elias Range, Canada. Journal of Geology 59(2):97-117.

Remnants of late Wisconsin drift on bedrock benches 800-1,500 feet above Wolf Creek are the oldest evidence of glaciation recognized. Deposits of very latest Wisconsin and possibly, in part, earliest post-Wisconsin drift are the product of a limited advance or extended pause in recession from the late Wisconsin climax. Wolf Glacier was then at least several hundred feet thicker, and its terminus was not less than 4 or 5 miles beyond the present snout. Post-Wisconsin xerothermic conditions caused extensive ice shrinkage, and the glaciers became smaller than at present. During this period an extensive valley train was formed, alluvial cones and fans were built, and a mature white spruce forest developed up-valley to its natural tree line. A subsequent expansion and readvance culminated between 1840 and 1890. Large raw lateral and terminal moraines and a trim-line in the mature spruce forest are the principal manifestations of this advance, which is believed to be of climatic, rather than orogenic or seismic, origin. Subsequently shrinkage, recession, and stagnation have ruled. The lower 9 miles of Wolf Glacier are stagnant, and this section has experienced 350-500 feet of vertical ablation, with terminal recession of only a few hundred yards. Degradation was interrupted by expansion and advance of certain favorably situated ice streams, starting in the late 1930s and extending into the 1940s. Slight rejuvenation also occurred in the uppermost stagnant part of Wolf Glacier. This reactivation was on the wane by 1947 and appears to have been but a minor interruption in the general shrinkage and degradation of the last fifty to a hundred years. Analysis of records suggests a climatic, rather than a seismic, cause for this recent rejuvenation.

A.A.

769. **SHAW, J., and J. ARCHER. 1978. Winter turbidity current deposits in late Pleistocene glaciolacustrine varves, Okanagan Valley, British Columbia, Canada. Boreas 7(3):123-130.**

Sand units within the winter clay components of distal, glaciolacustrine varves of Kickinlee Park, British Columbia show a common sequence of cross-lamination, and a similarity in grain size. A lower division of micro-cross-lamination is succeeded by two divisions of climbing ripple drift cross-lamination. The two upper divisions are differentiated on the basis of angle of climb, a marked increase occurring in the top division. The sequence is related to turbidity currents which swept down-lake during winter. It is possible that the B division of some turbidite sequences may have formed under conditions of low relief bedforms similar to those which generated the lower division of the glaciolacustrine sands. Stratigraphic position and varve thickness are used to support the conclusion that the distal turbidite sands are down-lake equivalents of proximal grain-flow deposits. The appearance of coarse grained deposits within winter layers of varves may cause two years of deposition to be allocated to a single varve. This may introduce large errors when varves are used as time indicators.

A.A.

770. **SHAY, C.T. 1966. Vegetation history of the southern Lake Agassiz basin during the past 12,000 years. In: Life, Land and Water. Edited by: W.J. Mayer-Oakes. University of Manitoba, Department of Anthropology Occasional Paper 1:231-252.**

Climate during the formation and subsequent fluctuations of Lake Agassiz I is indicated as being cool and moist. The forests consisted largely of spruce, larch, *Populus*, ash, and paper birch. Between 10-11,000 years ago a climatic warming occurred and *Populus*, birch, elm, pine and oak increased or migrated into the area, although they were not uniformly distributed. An increase of prairie suggests drier conditions began about 9,000 years ago. Between 7,000 and 8,000 years ago a period of maximum aridity occurred, roughly coinciding with the final disappearance of Lake Agassiz from the basin. Deciduous forest species increased shortly before 4,000 years ago; climatic conditions apparently became favourable. The author hypothesizes that Lake Agassiz had a significant influence on the climate, particularly along its eastern shores.

A.B.S.

771. **SHILTS, W.W. 1980. Flow patterns in the central North American ice sheet. Nature 286(5770):213-218.**

Patterns of glacial dispersal of lithologically distinctive erratics around Hudson Bay show the central portion of the North American Laurentide ice sheet to have been made up of at least two land-based centres, one that grew and dissipated in Keewatin, and one that grew and dissipated in Nouveau Quebec-Labrador.

A.A.

772. **SHORT, S.K. 1978. Palynology: a Holocene environmental perspective for archaeology in Labrador-Ungava. Arctic Anthropology 15(2):9-35.**

A series of six pollen diagrams has been prepared for lakes in northeastern Labrador-Ungava to investigate the chronology of deglaciation, the rate of plant colonization, and episodes of climatic change, and to provide a paleoenvironmental perspective for archaeological research in the area.

Thirty-eight C^{14} dates provide the chronological control, and show that the earliest organic records began at 10,500 B.P. There was a prolonged tundra episode at all the older sites, lasting from 2000 years up to 4000 years. This was followed around 6700-6500 B.P. by low-arctic shrub communities of dwarf birch and alder dominating the landscape for up to 200 years until open spruce woodland arrived, generally between 4500 and 4000 B.P. Spruce numbers declined after about 3000 B.P., and tundra has spread into former woodland since that time. This last period of colder climate has also seen a marked decline in lake productivity, as measured radiometrically by the rate of sediment accumulation. Thus, recent vegetational changes are difficult to analyze.

The prolonged episodes of tundra and shrub tundra development suggest that the early Archaic occupations of the Labrador coast preceded the arrival of spruce. Colder climatic conditions are correlated with the expansion of Dorset Eskimo into Labrador-Ungava.

A.A.

773. **SHORT, S.K., and J.T. ANDREWS. 1980. Palynology of six middle and late Holocene peat sections, Baffin Island. Géographie physique et Quaternaire 34(1):61-75.**

Palynological investigations were undertaken at six sites on the northern Cumberland Peninsula, Baffin Island. Pollen assemblages from the Canadian High Arctic are rare, and the purpose of this paper is to expand this record. Twelve pollen diagrams from the six sites are presented. They suggest that over the last 1000 years, the pollen rain has been dominated by pollen of the graminoid group. This contrasts with earlier pollen assemblages between 2500 and 2000 years BP and between 5000 and 4000 BP which were typically more diverse and included significant quantities of heath and shrub (willow) pollen. A pronounced willow peak is evident on the diagrams and dates from ca. 2500 BP.

A.A.

774. **SHORT, S.K., and J.D. JACOBS. 1982. A 1100-year paleoclimatic record from Burton Bay - Tarr Inlet, Baffin Island. Canadian Journal of Earth Sciences 19(3):398-409.**

The pollen study reported here from south of Frobisher Bay adds to our knowledge of late Holocene pollen spectra from Baffin Island, especially from the poorly known southern area. The Burton Bay Cliffs site registers two phases: an impoverished, grass-dominated phase, from ca. 1650 to 900 BP, and an earlier pollen assemblage dated ca. 2000-1650 BP, which was more diverse and included significant numbers of shrub (birch, willow, heath) pollen. The cooler and drier climatic conditions implied by the upper pollen zone are supported by the eolian deposition after 900 BP.

pA.C.

775. SHORT, S.K., and H. NICHOLS. 1976. Holocene palynology in subarctic Labrador-Ungava. American Quaternary Association, National Conference, Abstracts 4:116.

A series of six pollen diagrams has been prepared from lakes in northeastern Labrador-Ungava to investigate the chronology of deglaciation, the rate of plant colonization of the new landscape, and the climatic changes affecting the arctic tree line, as compared to northwest Canada. The relationships of Eskimo and Indian cultural history to environmental changes are being examined in cooperation with archaeological studies.

Twenty-seven ^{14}C dates provide the chronological control, and show that the earliest organic records began at 8700 BP. Initially, at all the older sites, there was a prolonged tundra episode, lasting up to one or two thousand years. This was followed metachronously by low-arctic shrub communities of dwarf birch and alder, dominating the landscape for many centuries until open spruce woodland arrived, generally about 4000 BP. Prior to the spruce arrival, there were long "tails" of low *Picea* numbers. Spruce numbers declined after about 3000 BP, and tundra has spread into former woodland since that time. The northward spruce migration was delayed relative to western arctic Canada, possibly due to marine influence on climate, but the subsequent southward expansion of tundra was synchronous in both regions. The last three thousand years of colder climate have also seen a very marked decline in lake productivity, as measured radiometrically by the rate of sediment accumulation. Thus, the topmost decimeters of these lake sediments date back several millennia, and should be used with great caution in comparing modern vegetation with "recent" pollen sedimentation.

A.A.

776. SHORT, S.K., and H. NICHOLS. 1977. Holocene pollen diagrams from subarctic Labrador - Ungava: vegetational history and climatic change. Arctic and Alpine Research 9(3):265-290.

Six pollen diagrams have been prepared for lakes in northeastern Labrador-Ungava in order to investigate the chronology of deglaciation, the rate of plantcolonization of the new landscape, and the climatic changes affecting the arctic tree line, as compared to northwest Canada.

Thirty-eight ^{14}C dates provide the chronological control, and show that the earliest organic records began at 10,300 BP. Initially, at all the older sites, there was a prolonged tundra episode, lasting up to 1000-2000 or more years. This was followed synchronously by low-arctic shrub communities of dwarf birch and alder, dominating the landscape for many centuries until open spruce woodland arrived, generally about 4000 BP. Prior to the spruce arrival, there were long "tails" of low *Picea* numbers. Spruce numbers declined after about 3000 BP, and tundra has spread into former woodland since that time. The northward spruce migration was delayed relative to western arctic Canada, possibly due to marine influence on climate, but the subsequent southward expansion of tundra was broadly synchronous in both regions. The last 3000 years of colder climate have also seen a very marked decline in lake productivity, as measured radiometrically by the rate of sediment accumulation. Thus, the topmost decimeters of these lake sediments date back several millennia, and should be used with great caution in comparing modern vegetation with "recent" pollen sedimentation.

A.A.

777. SHUKLA, J., and K.C. MO. 1981. Seasonal variation of blocking. First Conference on Climate Variations of the American Meteorological Society, January 19-23, San Diego, Abstracts, p. 9.

The daily 500 mb geopotential height fields over the Northern Hemisphere have been examined for 15 years. The frequencies of occurrence of events of persistent anomalies have been calculated, where anomaly is defined as the departure from the mean seasonal cycle. The amplitudes and the persistence characteristics of the anomalies are analyzed for each season separately. Most of the events of sufficiently large anomalies, which persist for several days, can be identified as "blocking."

A strong geographical and seasonal preference is found for the occurrence of blocking events. The vertical structure of selected blocking situations has also been examined.

A.A.

778. SIGLEO, W.R., and P.F. KARROW. 1977. Pollen-bearing Erie Interstadial sediments from near St. Mary's, Ontario. Canadian Journal of Earth Sciences 14(8):1888-1896.

The Wildwood Silts, of Erie Interstadial age (16 000 BP), occur between Catfish Creek Till (Nissouri Stadial) and Tavistock Till (Port Bruce Stadial) near St. Mary's, Ontario. Pollen analysis of a 16-m core through the silts yields a pollen assemblage dominated by pine and spruce pollen, resembling those reported from Port Talbot II and Plum Point Interstadial sediments in Ontario. A forest-tundra environment is inferred at the time of the Erie Interstadial, with generally sparse vegetative cover.

A.A.

779. SIMPSON, G.C. 1959. World temperatures during the Pleistocene. Quarterly Journal of the Royal Meteorological Society, London 85(366):332-349.

By a graphical method of trial and error a family of curves relating the zonal temperatures of all latitudes with the oscillations of the solar radiation is prepared and discussed. Results are tabulated and used to plot curves showing the variations of the zonal temperature of five latitudes (including 55°N and the North Pole) during a complete cycle of solar radiation and applied to the glacial and interglacial periods.

A.B.

780. SLATER, D.S. 1978. Late Quaternary pollen diagram for the central Mackenzie corridor area. American Quaternary Association, National Conference, Abstracts 5:176.

In conjunction with the Esker Bay Site archaeological excavation on the shore of Fish Lake, N.W.T., a small lake located at 63°0.86'N, 122°46.5'W, in the northern boreal forest, was cored to a depth of 268 cm for pollen analysis. The pollen stratigraphy derived from this study suggests a vegetational sequence extending back over 10,000 years. The sequence begins in a steppe-tundra assemblage dominated by *Artemisia*. This was succeeded by a *Betula-Salix* shrub-tundra, followed by a *Betula-Populus* forest-tundra. A *Picea-Betula-Alnus* dominated forest became established by approximately 6000 BP and has persisted since then with little change. *Pinus* increases in percentage, particularly during the last 2000 years, to reach its Holocene maximum at the present day, although still at levels suggesting long-distance transport.

With the exception of the recent high percentages for *Pinus*, the pollen stratigraphy closely resembles that from M Lake in the Mackenzie Delta area. As this is the first complete Holocene pollen record from the central portion of the Mackenzie Corridor, it bears important ramifications regarding both plant migration and prehistoric human utilization of this region.

A.A.

781. SMITH, P.J. 1981. New Brunswick perspective on climatic change. In: Climate Change Seminar Proceedings, Regina, March 17-19. Canadian Climate Centre, Downsview. pp. 33-42.

A survey of various departments of the New Brunswick provincial government by the New Brunswick Meteorological Committee indicated "that a change in our climate could have highly significant environmental, economic and social impacts in our province. However the magnitude of each impact depends upon the direction and amount of alteration in each meteorological parameter, and the relative sensitivity of specific activities."

A summary from a collection of the replies in response to this survey is provided, as an Appendix. Recommendations for action to help solve climate-related problems within the province are proposed.

A.B.S.

782. SORENSON, C.J. 1973. Interrelationships between soils and climate and between paleosols and paleoclimates; forest/tundra ecotone, north-central Canada. Ph.D. thesis, University of Wisconsin, Madison. 237 pp. Dissertation Abstracts International 34(10):5023B.

The objectives of this study were: 1) to examine the interactions of surface soils and modern climate; and 2) to determine from paleosols the positions of former forest/tundra borders and to estimate the characteristics of paleoclimates. Soil samples were collected from eskers at 40 sites in and in the vicinity of the forest/tundra ecotone of north central Canada. Interrelationships among soil properties and climatic measures were determined by multiple regression analyses so that the genesis of well-drained forest and tundra soils could be contrasted. Eleven of nineteen soil variables were significantly related to air mass measures of climate, suggesting that distinctive processes of soil genesis in forest and in tundra are dependent upon climatic conditions.

Paleosols uncovered in the course of this investigation indicate that the position of the forest/tundra border has varied from its present position at least seven times during the late Holocene. A combination of soil morphologic, biotic, and geomorphic evidence is used to plot the positions of former forest borders which varied from 280 km north of the present forest border to 50 km south. Major northward migrations of the forest occurred after 2900 BP, 1800 BP, and 800 BP. Southward movements of the forest border are recorded at about 3500 BP, 2600 BP, and 1600 BP.

Canonical correlation was used to associate sets of soil variables with sets of climate variables. A transformation function was derived from the canonical correlations which allowed the estimation of paleoclimates from paleosol data. The estimates suggest that paleoclimates were not much different than today's climate in the vicinity of the ecotone. Frequencies of Arctic air in summer, for periods when forests were 100 km farther north than they are today, were only about 5% to 10% less than they are at present. These estimates suggest that the frequency of cold dry conditions in summer is a critical factor in the limitations of the northward migration of forest.

pD.A.I.

783. SORENSON, C.J. 1977. Reconstructed Holocene bioclimates. Annals of the Association of American Geographers 67(2):214-222.

Paleopodzols and frost wedge polygons in and near the forest/tundra ecotone indicate that Holocene fluctuation of the forest border has varied from 280 km (170 mi) north to a minimum of 50 km (30 mi) south of the modern forest border in southwest Keewatin. The 320 km (200 mi) wide range for Keewatin appears to decrease systematically northwestward across Mackenzie and northeastward across Labrador. Significant forest/tundra border displacements occurred at least six times during the postglacial period in response to relatively conservative changes in the incidence of Arctic and Pacific derived air masses.

A.A.

784. SORENSON, C.J., and J.C. KNOX. 1973. Paleosols and paleoclimates related to late Holocene forest/tundra border migrations: Mackenzie and Keewatin, N.W.T. Canada. In: International Conference on the Prehistory and Paleoecology of Western North American Arctic and Subarctic. Edited by: S. Raymond and P. Schledermann. University of Calgary Archaeological Association. pp. 187-206.

Paleopodzols and frost wedge polygons in and near the forest/tundra ecotone indicate that Holocene fluctuation of the forest border has varied from 280 km (170 mi) north to a minimum of 50 km (30 mi) south of the modern forest border in southwest Keewatin. The 320 km (200 mi) wide range for Keewatin appears to decrease systematically northwestward across Mackenzie.

Canonical transform functions derived from correlation properties between surface soils and modern climatic variables were applied to characteristics of buried soils to reconstruct paleo airmass frequencies and former locations of the forest/tundra boundary for climatic episodes of the Holocene. Key periods of significant forest/tundra border displacement seem to have occurred at least six times during the post glacial period in response to relatively conservative changes in the incidence of Arctic and Pacific derived airmasses.

A.A.

785. SORENSON, C.J., J.C. KNOX, J.A. LARSEN, and R.A. BRYSON. 1971. Paleosols and the forest border in Keewatin, N.W.T. Quaternary Research 1(4):468-473.

The morphology of paleosols and radiocarbon-dated charcoal from buried surface horizons of soils provide evidence to suggest that between periods of northward forest encroachment tundra climate has dominated areas at least 50 km south of the present forest/tundra border in southwest Keewatin. The present forest/tundra border climate is nearly as severe as any climate that has prevailed in the area since deglaciation.

A.A.

786. STALKER, A.M. 1977. Indications of Wisconsin and earlier man from the Southwest Canadian Prairies. Annals of the New York Academy of Sciences 288:119-136.

The Taber Child is the most direct evidence for the presence of man on the Canadian Prairies before retreat of the last Wisconsin glacier. It consists of the skull and some other bones from a four-month-old child, found in alluvial sand some 60 feet below prairie level at a fresh exposure along the Oldman River just north of Taber, Alberta. Because the sand beds lie beneath a classical Wisconsin till, the child is at least 18,000 years old. Further, the bones compare in mineralization and preservation with mid-, or perhaps classical, Wisconsin bones recovered from near Medicine Hat, to the east. Elsewhere the unit that contained them has yielded radiocarbon dates on wood of >32,000 and >49,000 years. The best estimate of their age is about 40,000 years.

At the Reservoir Gully Site in Medicine Hat, Alberta, intertill beds of probable midclassical Wisconsin age contain fractured cherts that do not appear to have formed naturally. Because these beds are no older than those that contained the Taber Child, and are perhaps substantially younger, the fracturing could well have been done by man. In addition, older sites near Medicine Hat, and possibly others in Saskatchewan, have yielded cherts that appear to be fractured and flaked by man. These sites are in late Sangamon beds, probably between

120,000 and 80,000 years old. Both Reservoir Gully and the Sangamon sites contain abundant, scattered bones from animals well suited to support a human population.

Further, man's presence in North America prior to the last glacier advance has always seemed much more probable to me than the theories developed about man first proceeding south from Alaska, by a corridor between glaciers, towards the end of the Wisconsin Glaciation about 13,000 years ago--theories that were current and widely accepted when the Taber Child was found. The innumerable obstacles to migration at that time would include strong, chilling winds from the nearby glaciers, frequent periods of intense cold, ice barriers where active glaciers blocked the corridor, cold glacial lakes and tumultuous meltwater rivers to cross, not to mention the lack of vegetation or animals for firewood, clothing, and proper sustenance. Such obstacles have always seemed more formidable to me than the time difficulties associated with journeying south under favorable conditions in mid-Wisconsin or earlier time. This journey south from Alaska is, of course, a separate matter from the crossing of Bering Strait from Asia.

A.S.+

787. STALKER, A. MacS. 1980. The geology of the ice-free corridor: the southern half. Canadian Journal of Anthropology 1(1):11-13.

The concept of an ice-free corridor originally was introduced to explain an apparent sudden appearance of man in the southern half of North America about 13,000 years ago. Such a corridor, theoretically, would have enabled man to migrate southward through Canada, along the front of the Rocky Mountains, after entering the New World from Siberia by a land bridge provided by glacial lowering of the ocean. As a result, the concept of an ice-free corridor has always been associated with the movement of man, with the Classical Wisconsin glaciation, and generally with the latter part of that stage.

In conclusion, the growing realization in recent years that the Classical Wisconsin glacier was much weaker and less extensive than previously thought greatly enhances the chances of there having been an ice-free corridor. The logical time for such a corridor suitable for migration of man, during Classical Wisconsin time, was about 19,000 years ago during a mid-Classical Wisconsin interstade. Meanwhile, although the likelihood of such a corridor has increased, the finding of indications of man in North America from even earlier times has lessened the need for it. Howbeit, even if man were in the New World prior to Classical Wisconsin glaciation, any available corridor undoubtedly would have been used for fresh waves of migration from Asia, and perhaps also in the reverse direction.

Excerpts

788. STENE, L.P. 1980. Observations on lateral and overbank deposition--Evidence from Holocene terraces, southwestern Alberta. Geology 8(7):314-317.

Evidence from terrace sequences in southwestern Alberta shows that overbank deposition rather than lateral accretion was the dominant form of sedimentation during the Holocene. The thin basal gravels along most terrace exposures were deposited by lateral-accretion processes similar to those operating within present-day channels and flood plains. The thicker, overlying sediments are fine-grained and were produced mainly by overbank deposition from high-discharge events. A less erosive overbank environment for the latter is supported by the presence of undisturbed tephra and archaeological cultural horizons. The overbank deposition appears to have resulted from the combined effects of intense rainfall and fire denudation of forested slopes.

A.A.

789. STRAIN, P.M., and F.C. TAN. 1979. Carbon and oxygen isotope ratios in the Saguenay Fjord and the St. Lawrence Estuary and their implications for paleoenvironmental studies. Estuarine and Coastal Marine Science 8(2):119-126.

Surface water samples (1 m depth) from the Saguenay Fjord and the upper St. Lawrence Estuary have been analysed for $\delta^{13}C$, ΣCO_2, and $\delta^{18}O$. In the Saguenay Fjord, the $\delta^{13}C$ PDB and concentration of the total dissolved CO_2 vary from $-10.9^{0}/_{00}$ and 3.6 ml/l near the head to $-0.4^{0}/_{00}$ and 30.3 ml/l at the mouth. The upper St. Lawrence Estuary exhibits a $\delta^{13}C$ range of -4.2 to -1.6 and a ΣCO_2 concentration range of 19.8 to 37.6 ml/l.

The measured $\delta^{13}C$, ΣCO_2, $\delta^{18}O$ and salinity distributions are compared to a conservative mixing model. The excellent agreement between the measured and predicted $\delta^{13}C$ values in the Saguenay Fjord indicates that the carbon isotope ratio behaves conservatively. In the upper St. Lawrence Estuary, the much poorer agreement suggests that significant in situ processes involving the dissolved CO_2 are operative.

The suggestion that estuarine paleotemperatures may be obtained by extrapolating $\delta^{13}C$-$\delta^{18}O$ shell carbonate curves to marine conditions is open to criticism. The $\delta^{13}C$-$\delta^{18}O$ water curves observed in this work illustrate two different situations that could produce errors in paleotemperatures estimated by this method.

A.A.

790. STUCKENRATH, R., G.H. MILLER, and J.T. ANDREWS. 1979. Problems of dating Holocene organic-bearing sediments, Cumberland Peninsula, Baffin Island, N.W.T., Canada. Arctic and Alpine Research 11(1):109-120.

In 1973, several samples of buried organic-bearing sediments were collected from beneath and within the "layered sands" of Pangnirtung Pass and the Padle/Kingnait Pass, eastern Baffin Island, N.W.T. Radiocarbon dates on some samples yielded apparent ages in conflict with their stratigraphic position, and it was clear that contamination was present within these well-drained sediments. In 1974, three sites were revisited and larger (>3000 g) samples were collected. Organic content varied between 2.5 and 8.2% by weight. We report the results of 28 individual age determinations, stratified according to (1) different laboratory preparations, (2) different size fractions of the organic materials, and (3) different NaOH solubility fractions. Statistical analysis of these data indicated that in no instance could we reject a null hypothesis, and hence no statistically significant trends could be outlined. Differences in age within a sample varied between 720 and 1245 yr. We suggest that the most reliable fraction for dating these sediments is the <125-μm organic fraction which is insoluble in NaOH. However, the >125-μm NaOH-insoluble fraction gave ages consistently younger than in the <125-μm NaOH-insoluble fraction. These age differences might be associated with a soil residence time for the finer fraction.

A.A.

791. STUPART, R.F. 1917. Is the climate changing? Journal of the Royal Astronomical Society of Canada 11(4):197-207.

Sir Frederic reasoned that deforestation would produce a tendency towards slightly warmer summers and colder winters in Ontario. From study of the earliest Canadian climatic information in the Relations of the Jesuits, he concluded that the climate of Quebec in the 17th Century was then much as it is in the early Twentieth Century. Sir Frederic concluded that precipitation data at Toronto give ground from some suspicion that the annual rainfall has diminished somewhat since 1840. Regarding temperature, he saw a manifest tendency towards higher mean spring, summer and annual temperatures during the past 20 odd years, while any upward winter tendency is less noticeable. Also, in the early days of the observatory, frost seemed to have occurred later and been more severe than in recent years. The Montreal record gives no apparent indication of change. At Winnipeg, winters have been milder during the past 17 years than during the first three decades. Precipitation figures are indicative of no permanent tendency. The Edmonton record is short, but the cold winters of the '80s are clearly shown, while data indicate that summers have not deteriorated. There is evidence that 1897 ended a comparatively dry precipitation cycle, since summer rains have been more ample since that year.

Thomas

792. SUESS, H.E. 1956. Absolute chronology of the last glaciation. Science 123(3192):355-357.

Contains a reconstruction of the climate of the Northern Hemisphere for the last 100,000 years based largely on dating of radioactive deposits from the continent and the deep sea. Evidence is presented for two superimposed climatic fluctuations of 40,000 and 3,500 years each, the last glaciation covering at least two of the long periods.

A.B.

793. SUESS, H.E. 1968. Climatic changes, solar activity, and the cosmic-ray production rate of natural radiocarbon. In: Causes of Climatic Change. Edited by: J.M. Mitchell, Jr. Meteorological Monographs 8(30):146-150.

The level of the cosmic-ray-produced radiocarbon in atmospheric carbon dioxide fluctuates due to changes in the cosmic-ray intensity. These changes can be explained by considering the modulation of the galactic cosmic-ray flux by the sun. There exists a second independent correlation of the fluctuations of the radiocarbon level with changes in the climate. This correlation can best be recognized from climatic data as given by Lamb for the time since the 10th century A.D. The two kinds of correlations promise to provide a key to the understanding of solar-climatic relationships in general. The carbon-14 measurements so far carried out show that prolonged high solar activity leads to warm winters, and periods of a quiet sun lead to cold winters in Europe and elsewhere. There is reason to believe that future determinations of carbon-14 variations during the past 6000-8000 yr may supply conclusive evidence regarding the causes of the great ice ages.

A.A.

794. SWANSON, E.H., Jr. 1965. Ecological communities in Northwest prehistory. In: Proceedings of the 7th Congress, International Association for Quaternary Research. Quaternaria 8:91-99.

At the time of contact with European man, Indians in the Pacific Northwest were closely adapted to their natural setting, for they made their living by hunting, fishing, and gathering. The efficient use of salmon, deer, and wood on the Northwest Coast is as well known as the seed gathering of the Great Basin and the big-game hunting of the Northern Rocky Mountains. Although this is a common observation, well documented in the literature, it can be made to serve a particular purpose in the study of regional prehistory.

That purpose is the use of prehistoric environments as a basis for examining the history of particular cultures and, perhaps, the evolution of culture in the Northwest. It may then be possible to separate cultural from environmental factors in the cultural history. If the natural surroundings of similar and different cultures can be analyzed with sufficient control, then it may be possible to isolate those aspects of culture that have made it possible for man to free himself increasingly from the control of his environment. In northwestern North America, environmental concepts and methods may be applied because there exist many excellent studies of geology, geography, and botany (Daubenmire, 1943; Dort, 1965; Fryxell and Daugherty, 1963; Hansen, 1947; Heusser, 1960). Further, archaeologists have made good use of environmental studies in the excavation of a number of important prehistoric sites, although some of this work remains unpublished.

A.A.

795. SZABO, B.J., G.H. MILLER, J.T. ANDREWS, and M. STUIVER. 1981. Comparison of uranium-series, radiocarbon, and amino acid data from marine molluscs, Baffin Island, Arctic Canada. Geology 9(10):451-457.

Uranium-series and ^{14}C dates and the extent of amino acid racemization are reported for 24 marine shell samples from three areas of Baffin Island, Arctic Canada. When the radiometric dates are plotted against the ratio of D-alloisoleucine: L-isoleucine in the shells, five broad age groups are recognized. The uranium-series data indicate that ^{231}Pa is incompletely retained in most fossil shells and that ^{230}Th is lost from some of the samples. Therefore, their apparent ages are minimum. However, a few dated samples in each group have yielded useful age results, and the minimum ages of the five groups of samples are estimated as 7,000 to 11,000, >70,000, >136,000, >190,000, and >300,000 yr. Calculated integrated thermal histories based on the epimerization reaction in the mollusc *Hiatella arctica* Linné give paleotemperature estimates of around -5°C, compared to the present mean annual air temperature of about -11°C.

A.A.

796. TANDE, G.F. 1978. Management implications of historic fire periodicity in relation to changing climate. In: Fire Ecology in Resource Management Workshop Proceedings, December 6-7, 1977. Edited by: D.E. Dube. Canadian Forestry Service Information Report NOR-X-210. Edmonton, pp. 17-19.

Specific causal factors leading up to historic fires are not known, although a combination of weather and climatic factors may induce drought which increases the probability of fire. Implications of the relationship between fire and climate thus have potential significance for ecologists and land managers. Forest fire history of the Athabasca River valley around Jasper townsite, Jasper National Park was used as a basis for discussing some management implications of fire periodicity in relation to changing climate.

Fire scars were used to establish a fire chronology for the period 1665-1975. The mean fire return interval (MFRI) for the 43200 ha study area was 4.4 yrs and 5.5 yrs from 1665-1907. Major fires (500 ha) occurred every 8.4 yrs. Fires covering more than 50% of the area (1889, 1847, 1758) had a MFRI of 65.5 yrs.

Comparisons with other fire history studies in the Canadian Rockies indicated that frequency and areal extent of forest fires were similar throughout the region, in spite of the fact that the areas did not experience similar human-use patterns. The area burned per year in the study area fluctuated erratically and was not well correlated with human-use patterns.

The size of fires increased exponentially with time, terminating with very large fires such as those in 1889, 1847 and 1758. These irregular exponential curves were attributed to climatic oscillations and variations of fuel buildup with time. A deudroclimatology record was used to assess major drought years or potential fire years. About 70% of the fires and 92% of the total area burned from 1700-1913 occurred during below-mean precipitation periods. The 1758[1], 1847 and 1758 fires occurred during severe droughts. This and other studies showed many fire years in common, suggesting major atmospheric circulation anomalies associated with subcontinental drought. It was therefore concluded that climate was the principal factor that controlled the frequency and extent of past fires.

Excerpts

797. TARNOCAI, C., and S.C. ZOLTAI. 1978. Earth hummocks of the Canadian Arctic and Subarctic. Arctic and Alpine Research 10(3):581-594.

Studies in the western Arctic and Subarctic and in the central Arctic indicate that earth hummocks have an average diameter of 80 to 160 cm and an average height of 40 to 60 cm. They have developed on materials that have 58 to 99% total clay and silt content and either high ice content or pure ice layers in the near-surface permafrost. Earth hummocks are cryogenic in origin with their development being controlled by three major factors: soil texture, soil moisture, and soil temperature. Most of the earth hummocks have developed during the last 5000 yr, when the climate became colder.

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[1] Ed. note: Presumably this should read "1889".

A.A.

798. **TAYLOR, A., and A. JUDGE. 1979. Permafrost studies in northern Quebec. Géographie physique et Quaternaire 33(3-4):245-251.**

In cooperation with mining companies, temperature data are being acquired at several sites in the Cape Smith - Wakeham Bay Belt of Northern Quebec. Cables, containing up to twenty thermistors, are lowered into exploratory diamond-drill holes upon completion, and allowed to freeze in place. Three temperature profiles at Asbestos Hill yield low geothermal gradients; thermal conductivities of core are moderate to low and hence low values of the terrestrial heat flow are observed. Extrapolating temperature profiles to greater depths gives a permafrost thickness of at least 540 m. The uncorrected terrestrial heat fluxes calculated for the shallow holes are about 2/3 that of the lower section of the deeper hole. Such contrast in heat flow is used to develop a simple model of surface temperature history for the area for the past 85000 years. Using this geothermal data, engineering estimates may be made of such parameters as maximum active layer thickness and thaw penetration of both open pit walls and underground drifts.

The geothermal data examined in this study generally support palaeoclimates proposed by other disciplines for the past several thousand years. The probable heat flux for this area, corrected for a reasonable climatic history, is 38 ± 5mWm^{-2}.

A.A.+

799. **TEDROW, J.C.F. 1972. Soil morphology as an indicator of climatic changes in the Arctic areas. In: Climatic Changes in Arctic Areas During the Last Ten-Thousand Years. Edited by: Y. Vasari, H. Hyvärinen and S. Hicks. Acta Universitatis Ouluensis Series A, Scientiae Rerum Naturalium 3, Geologica 1:61-74.**

The possiblities of using pedologic information to reconstruct past climates of the arctic region are considered. The arctic region is divided into three soil zones: (1)Polar Desert, (2) Subpolar Desert and (3) Tundra, with zonal boundaries corresponding approximately to high arctic, mid-arctic and low arctic, respectively. Within each zone, four genetic varieties of soil are listed. The old landscapes of the far north of North America including Greenland, have certain soil properties which suggest a past warmer climate. The time under consideration in these sectors, however, is Early Pleistocene or possibly Late Tertiary. Within the Tundra and Polar Desert soil zones, buried organic matter was studied with respect to age and pollen composition. Ages of the buried organic matter ranged form 1,200 to 10,600 yr BP. Pollen from the buried organic layers is similar to that of the present with some buried samples indicating possibly warmer conditions.

The buried organic matter which is as much as 4-feet-deep probably reached its present position during a warmer episode at which time there was deeper seasonal thaw in the soil, which in turn would suggest warmer summer temperatures. Several cases of buried soil profiles are considered along with paleoclimate implications.

pA.A.

800. TELLER, J.T., and M.M. FENTON. 1980. Late Wisconsinan glacial stratigraphy and history of southeastern Manitoba. Canadian Journal of Earth Sciences 17(1):19-35.

The history of Late Wisconsinan glaciation in southwestern Manitoba has been established by identifying and correlating ice-laid lithostratigraphic units in the subsurface. Five Late Wisconsinan tills are defined on the basis of their texture, mineralogic composition, and stratigraphic position. These new formations are, from youngest to oldest, Marchand, Whitemouth Lake, Roseau, Senkiw, and Whiteshell Formations.

Late Wisconsinan ice first invaded southeastern Manitoba 22 000 to 24 000 years ago. This Laurentide glacier advanced from the northeast across the Precambrian Shield and deposited the sandy Whiteshell and Senkiw tills, which contain abundant Precambrian rock fragments and minerals and few Paleozoic carbonate grains. Shortly after this, Keewatin ice advanced from the northwest over Paleozoic carbonate rocks, depositing the loamy carbonate-rich Roseau Formation throughout most of the area. This ice remained over southeastern Manitoba until after 13 500 years ago, when it rapidly retreated northward with Lake Agassiz on its heels. Two brief glacial readvances occurred. The first overrode Lake Agassiz lacustrine sediment as far south as central North Dakota shortly after about 13 000 years ago. The clayey Whitemouth Lake till was deposited in southern Manitoba at this time. After a rapid retreat, the ice briefly pushed southward over southeastern Manitoba about 12 000 years ago to just south of the International Boundary. The sandy carbonate-rich Marchand Formation was deposited at this time as the ice overrode its own sandy outwash. By 11 000 years ago, ice had disappeared from southeastern Manitoba.

A.A.

801. TELLER, J.T., and W.M. LAST. 1981. Late Quaternary history of Lake Manitoba, Canada. Quaternary Research 16:97-116.

The postglacial history of Lake Manitoba has been deduced from a study of the changes in physical, mineralogical, and chemical variables in sediment cores collected from the lake. Six lithostratigraphic units are recognized in the South Basin of the lake. Weakly developed pedogenic zones, reflecting dry or extremely low water conditions in the basin, separate five of these six units. The initial phase of lacustrine sedimentation in the Lake Manitoba basin began shortly after 12,000 yr BP as water was impounded in front of the receding glacier to form Lake Agassiz. By 11,000 yr ago, continued retreat of the ice sheet opened lower outlets to the east and much of Lake Agassiz drained, including the Lake Manitoba basin. Water levels again rose at 9900 yr BP, but by about 9200 yr BP the South Basin was again dry. For the next 4700 yr there was an alternation of wet and dry conditions in the basin in response to the interaction of a warmer and drier climate and differential crustal rebound of the basin. About 4500 yr ago a new phase of Lake Manitoba sedimentation was initiated when the Assiniboine River began to discharge into the South Basin. The Assiniboine River was diverted out of the Lake Manitoba watershed about 7200 yr ago. Erosion and redistribution of the sandy deltaic sediments deposited by the Assiniboine River has created the barrier beach that now separates the extensive marsh to the south of the lake from the main lake.

A.A.

802. TERASMAE, J. 1956. Palynological study of Pleistocene deposits on Banks Island, Northwest Territories, Canada. Science 123(3201):801-802.

The locality from which the samples were collected is in the general vicinity of Cape Kellett along the western shore of Banks Island, approximate lat. 72°N, long. 120°W... The palynological study suggests that, at the time when the beds from which the samples were collected were deposited, considerably more favorable climatic conditions than those now prevailing must have been present on Banks Island to account for the assemblage of pollen grains, spores, and other plant fossils present in these deposits. The total assemblage and relative numbers of pollen grains further suggest local forest coverage. The present timber line lies about 200 mi southwest of Banks Island.

Excerpt

803. TERASMAE, J. 1957. Paleobotanical studies of Canadian Pleistocene nonglacial deposits. Science 126(3269):351-352.

Results of "a palynologic study of certain nonglacial deposits in the St. Lawrence lowland, Quebec, and in the James Bay lowland, Ontario... warrant an assessment of the climate of the nonglacial interval and of the stratigraphic positions of the deposits." Radiocarbon determinations of peat and wood samples provided ages of >38,000 yr for nonglacial deposits on the Missinaibi River and >40,000 yr for nonglacial deposits in the St. Lawrence lowland. "The palynologic evidence indicates that boreal conditions prevailed during most of the nonglacial interval in both areas and that the temperature did not reach a maximum as warm as that of the present. An arctic and subarctic environment is evident at the beginning and close of the interval (relatively high percentages of birch, alder and nontree pollen)." In the early and late parts of the interval the predominant trees were black spruce (*Picea mariana*) and white spruce (*P. glauca*). Slightly warmer conditions are indicated during the middle of the interval by higher values of pine pollen (*Pinus banksiana*).

A.B.S.

804. TERASMAE, J. 1959. Palaeobotanical study of buried peat from the Mackenzie River delta area, Northwest Territories. Canadian Journal of Botany 37(4):715-717.

A palaeobotanical and palynological study of samples of buried peat from the Mackenzie River delta area, Northwest Territories, has shown that the peat accumulated during an interglacial interval. For reference purposes a study of modern pollen of *Rubus chamaemorus* L. and of four species of *Drosera* L. has been made.

A.A.

805. TERASMAE, J. 1960. Contributions to Canadian palynology No. 2. Part I. A palynological study of post-glacial deposits in the St. Lawrence Lowlands. Geological Survey of Canada Bulletin 56:1-22.

After the retreat of the ice, lacustrine conditions prevailed over the part of the St. Lawrence Lowlands between Montreal and Quebec City. This was followed by the marine inundation known as the Champlain Sea.

Over much of the area occupied by the Champlain Sea, bogs were subsequently developed and a study of the pollen content of those bogs has led to the recognition of six pollen zones. The oldest of these started to form some 9,000 years ago when the sea stood at about the position of the present 250-foot contour, 200 feet or so below its maximum.

Although marine fossils are largely absent in deposits below this level, the pollen content of the bogs shows that they started to form in an orderly sequence from higher to lower levels. Thus, by means of palynological studies terraces on either side of the river may be correlated.

A.A.

806. TERASMAE, J. 1960. Contributions to Canadian palynology No. 2. Part II. A palynological study of the Pleistocene interglacial beds at Toronto, Ontario. Geological Survey of Canada Bulletin 56:23-41.

Interglacial sands, silts, and clays are exposed in the Don Valley brickyard and the Scarborough bluffs along the shore of Lake Ontario at Toronto. The basal beds consist of York till separated by a time interval from the overlying nonglacial beds. These are subdivided into the Don beds at the base and the Scarborough beds above, which are separated from each other by a hiatus and possibly a short glacial episode. The glacial beds above this are subdivided into the Sunnybrook till, the Danforth beds, and the Thorncliffe beds, in ascending order.

Palynological and palaeontological studies show that Don beds were laid down when the annual mean temperature was warmer by some 5°F than now, and the Scarborough beds when it was some 10° colder.

The Don beds were certainly deposited during an interglacial period, possibly to be correlated with the Sangamon. The Scarborough beds are tentatively assigned to the St. Pierre interval and may have formed during a substage in the onset of the Wisconsin stage proper.

A.A.

807. **TERASMAE, J. 1961. Muskeg: its environment and uses. In: Proceedings of the Seventh Muskeg Research Conference. National Research Council of Canada, Ottawa. pp. 1-8.**

Defines muskeg as "a specific type of environment, caused and affected by a number of climatic, edaphic and biological factors." Climatic and drainage conditions favorable to its development are considered. Research studies are noted. Use of peat and muck areas for farming, fuel, and as a record of past plant and animal life as well as of climatic changes, is discussed, with examples from author's collecting across Canada.

A.B.

808. **TERASMAE, J. 1961. Notes on late-Quaternary climatic changes in Canada. Annals of the New York Academy of Sciences 95(1):658-675.**

Reviews the various sources of paleoclimatic information on Canada, under meteorology, glacial geology, oceanography, paleontology, botany, soils, and palynology. Edaphic, genetic, and geologic factors are suggested for consideration in reaching paleoclimatologic conclusions. Palynological studies in Northern Ontario and Quebec indicate a possible recurrence of glaciation with a 5°-10°F fall in mean summer temperatures. More paleoclimatic information may be found in the Canadian Arctic than hitherto expected. Unusual atmospheric circulation may contribute to the small ice caps on Baffin, Devon, and Ellesmere Islands; presence of unglaciated areas is not completely explained. Time equivalence of late-Quaternary climatic changes is the basic requirement for all correlations using palynological and paleontologic evidence. Migration rates for plants and animals constitute a factor important in paleoclimatology.

A.B.

809. **TERASMAE, J. 1963. Problems of pollen zone correlation in southeastern Canada. Grana Palynologica 4(2):313-318.**

The author discusses palynolgical studies made in the region of Canada including the Maritime Provinces and southeastern Quebec. After pollen zones had been determined for local areas, the need for regional correlation of zones became apparent. The author's studies have revealed several problems when such correlation has been attempted. Factors influencing the invasion of the area by plant species after glacier retreat include the Champlain Sea episode in the St. Lawrence Valley region, the effect of the icesheet on vegetation at its margins, and a climatic zonation which appears to have an east-west trend.

A.B.S.

810. **TERASMAE, J. 1963. Notes on palynological studies of varved sediments. Journal of Sedimentary Petrology 33(2):314-319.**

The writer suggests that the term varved should be restricted to laminated and graded sediments (both inorganic and organic) of annual, or seasonal (composed of a winter and a summer layer) origin where such nature can be established. He has shown by palynological methods the annual origin of varved clays in the Glacial Lake Barlow - Ojibway basin in northern Ontario, where a total of 2027 varves has been counted by Antevs (1925) and Hughes (1956). In this case the varve counts can be used as a time scale for certain events. Laminated sediments of other than annual origin and those resembling varves only in appearance should be clearly distinguished from the true varved sediments.

A.A.

811. TERASMAE, J. 1965. Surficial geology of the Cornwall and St. Lawrence Seaway Project areas, Ontario. Geological Survey of Canada Bulletin 121:1-54.

Evidence has been found of three different movements of glacier ice - Malone, Fort Covington, and a post-Fort Covington readvance. The Champlain Sea covered the area some 10,000 to 11,000 years ago, and freshwater organic sediments began to accumulate more than 9,430 ± 140 years B.P. as shown by radiocarbon dating.

Palynological studies indicate that the early forest, about 9,500 years ago, was composed of spruce, balsam fir, jack pine, and birch, with a minor component of hardwood species. An improvement in climate followed, and the early boreal forest was replaced by a mixed hardwood forest with pine and hemlock. The clearing of land in historic time was marked by a sudden increase in weed pollen.

A.A.

812. TERASMAE, J. 1965. A review of palynological studies in eastern Maritime Canada. Maritime Sediments 1(2):19-22.

The author briefly reviews past and present maritime palynological studies. Each study is reported in terms of its geographical location, and the sources from which samples were collected for analysis. Twenty-seven studies are recorded, however no specific results are presented for any one.

A.B.S.

813. TERASMAE, J. 1967. A review of Quaternary palaeobotany and palynology in Canada. Geological Survey of Canada Paper 67-13:1-12.

A review of Quaternary palaeobotany and palynology in Canada shows a development from the early exploratory studies before 1900 to more systematic investigations after 1940. Extensive peat bog surveys in the early nineteen hundreds stand out because of their economic objectives. Since 1930 palynological studies have become dominant over investigations of plant macrofossils. In recent years the potential usefulness of palaeobotanical studies in both physical and biological sciences dealing with our natural environment has been clearly established. The methods used in palaeobotanical research have become more precise and versatile and allow an improved assessment of the basic hypotheses employed in the interpretation of the Quaternary palaeobotanical and palynological record.

G.A.

814. TERASMAE, J. 1967. Recent pollen deposition in the northeastern District of Mackenzie (Northwest Territories, Canada). Palaeogeography, Palaeoclimatology, Palaeoecology 3(1):17-27.

Surface samples of peat, soil, and lake sediments collected by W. Blake in the Bathurst Inlet-MacAlpine Lake area while studying glacial history were examined for pollen grains and spores. The pollen-and-spore assemblages obtained reflect the characteristics of local vegetation and contain a significant component of pine and spruce pollen from a distant source area. The area studied lies 200-250 miles north of the tree-line. A study of peat deposits has indicated that the meteorological factors influencing long-distance dispersal of pollen have remained essentially unchanged for the last 2,000 years. This study also suggests that peat deposition has been extensive only in Late Postglacial time, and commonly an important discontinuity separates the surface peats from the underlying inorganic deposits in the MacAlpine Lake area.

A.S.

815. TERASMAE, J. 1967. Notes on Quaternary palaeoecological problems in the Yukon Territory, and adjacent regions. Geological Survey of Canada Paper 67-46:1-11.

The Yukon Territory has attained a prominent place among problem areas in Canada for Quaternary research, because parts of northern Yukon are unique in that they remained unglaciated throughout the Quaternary. Geological and palynological studies have indicated the presence of a long palaeoecological record in the unglaciated region, but this record is broken by frequent and important discontinuities. The recycling of deposits by erosion and redeposition, and their permanently frozen condition complicate the studies. Possible migration of plants across the postulated Bering Sea land bridge introduces several as yet poorly known factors into palaeobotanical investigations. Available evidence indicates that Quaternary climatic changes in Yukon have been approximately contemporaneous with, and probably of the same magnitude as those further south in the temperate latitudes. Palaeoecological evidence indicates that human migration could have occurred from Asia to Yukon and hence southward in late-Quaternary time, some 14,000 years ago, or possibly even earlier in the mid-Wisconsin nonglacial interval. Recent archaeological studies have confirmed the probable presence of human occupation in Yukon during late-Quaternary time. The late-Quaternary extinction of several mammal species in Yukon is an interesting problem; whether it occurred because of changing palaeoecological conditions or from other causes remains to be explained.

A.A.

816. TERASMAE, J. 1967. Paleoecology: a practical viewpoint and general considerations. In: Life, Land and Water. Edited by: W.J. Mayer-Oakes. University of Manitoba, Department of Anthropology Occasional Paper 1:207-215.

This is a general review of paleoecology with special emphasis upon its relationship to the human environment, the myth of unlimited resources, the water crisis and pollution, the problems of pesticides and conservation and the search for new natural resources.

G.A.

817. TERASMAE, J. 1967. Postglacial chronology and forest history in the Northern Lake Huron and Lake Superior regions. In: Quaternary Paleoecology. Proceedings of the VII INQUA Congress. Edited by: E.J. Cushing and H.E. Wright, Jr. pp. 45-58.

Geochronological studies have indicated that the region immediately north of Lake Huron and Lake Superior was covered by the continental ice sheet during the Valders subage. Deglaciation about 10,000 years ago was accompanied by a complex sequence of ice-dammed lakes, with rapidly changing levels, extents, and outlets. High shorelines north of Sault Ste. Marie at about 1,025-ft. elevation indicate that Glacial Lake Algonquin extended into the Lake Superior basin. The assumed Nipissing shoreline at Little Pic River, west of White River, Ontario, has been dated at about 5,900 years B.P. It is suggested that Glacial Lake Agassiz, west of Lake Superior, was in part contemporaneous with Glacial Lake Algonquin.

Species of arctic plants migrated into this region and reached the headwaters of rivers flowing north and northeast more than 9,000 years ago, and the arctic species were crowded out except in localities with rather unique ecological conditions, such as the rugged shore bluffs of Lake Superior, where they have survived to the present. Some boreal species (e.g.

Pinus strobus) ranged north of their present distribution limits during the hypsithermal interval, which was followed by considerable areal expansion of muskeg. Forest fires have been a significant ecological factor in most of this region throughout postglacial time, as indicated in the Red Lake area by consistently high percentages of jack pine (*Pinus banksiana*) and birch (*Betula*) pollen.

G.A.

818. TERASMAE, J. 1968. A discussion of deglaciation and the boreal forest history in the northern Great Lakes region. Proceedings of the Entomological Society of Ontario 99:31-43.

The early postglacial boreal forest in northern Ontario differed from that which occupied the same region during the rest of postglacial time, because of both geolgical and climatological factors. For example, in the Hudson Bay and James Bay lowland the general slope of the land to the east and northeast was greater than now, because the isostatic rebound from glacial loading which had depressed the crust in the Hudson Bay region was just beginning. This condition provided for better drainage at that time. In addition, there is evidence to indicate that climatic conditions were probably both warmer and maybe drier at the same time, between 7,000 and 5,000 years ago. The subsequent trend towards increased moisture regime and later a change to cooler climatic conditions some 3,000 or 2,500 years ago certainly favored expansion of muskeg. The climatic trend was, furthermore, accompanied by isostatic uplift which caused a decrease of slope towards Hudson Bay and a corresponding deterioration of drainage.

Evidence for a warmer episode (the hypsithermal) is provided by paleobotanical studies which have indicated that, for example, the white pine range extended north of its present limit by some 60 miles or more just prior to 5,000 years ago, according to radiocarbon dates on buried white pine fossils at Val St. Gilles, Quebec. Both peat stratigraphic studies and radiocarbon dating have indicated that considerable expansion of muskeg occurred in the northern Ontario Clay Belt in late postglacial time.

Excerpt

819. TERASMAE, J. 1968. Some problems of the Quaternary palynology in the western mainland region of the Canadian Arctic. Geological Survey of Canada Paper 68-23:1-26.

The problems concerning palynological studies of Quaternary deposits in the western Canadian Arctic are summarized and evaluated, and the relatively greater importance of certain aspects of pollen production, dispersal and deposition in the Arctic than in the more southern latitudes is pointed out. In the interpretation of the fossil pollen record the discussion emphasizes the need for awareness of limiting factors evident in palynological techniques. It is important to integrate palynological interpretations with evidence obtainable from other sources, such as glaciology, Quaternary geology, climatology, dendrochronology, geobotany and ecology, in order to suggest meaningful paleoecological and paleoclimatological reconstructions. The results indicate a causal relationship between Arctic vegetation and climate and hence, confirm the validity and usefulness of palynological studies in the investigation of postglacial and Quaternary environmental changes in the Arctic region.

A.A.

820. TERASMAE, J. 1969. Quaternary palynology in Quebec: a review and future prospects. La Revue de Géographie de Montréal 23(3):281-288.

This review points out that Québec was, in effect, the birthplace of Canadian Quaternary palynology. The early studies were concerned with peat resources and from these developed palynological studies when the usefulness of pollen stratigraphy in correlation, climatic studies and vegetation history was realized. In the 1950s several major projects were initiated and with the support of radio-carbon dating the palynological studies became increasingly helpful for geological investigations. However, in spite of the progress made our present knowledge of palynology in Quebec has not extended past the preliminary phase of reconnaissance which has, nevertheless, clearly indicated the potential value of palynological research. The greatest current needs are training of palynologists and providing financial assistance for basic palynological research in particular because without an adequate basic knowledge the full potential of this research cannot be realized. A summary of needs and priorities in Quaternary palynology is given in the last part of this review.

A.A.

821. TERASMAE, J. 1972. The Pleistocene-Holocene boundary in the Canadian context. 24th International Geological Congress, Section 12:120-125.

At the 1969 meeting in Paris the INQUA Subcommission for the Study of the Holocene recommended that the Pleistocene-Holocene boundary be defined in terms of a significant climatic change and a type section (international stratotype) where evidence (geological, biological and other) for this change would be available for examination. The age of this boundary was proposed to be 10,000 radio-carbon years before present.

About 10,000 years ago, a substantial part of Canada was still covered by the residual mass of the continental ice sheet. This report draws attention to some of the problems that are related to the establishment of the Pleistocene-Holocene boundary in Canada, and some of the criteria that could be used for defining this boundary.

pA.A.

822. TERASMAE, J. 1973. Notes on late Wisconsin and early Holocene history of vegetation in Canada. Arctic and Alpine Research 5(3):201-222.

Nearly all of Canada was covered by the Wisconsin glaciation and most of the country was deglaciated during the time about 12,000 to 7,000 years ago. The biota generally survived the glaciation south of the ice sheets in North America, in addition to survival in probable refugia along the coasts and in Yukon and the Arctic Islands.

The ice sheets (Laurentide and Cordilleran) completely disturbed the vegetation in Canada. As deglaciation occurred in response to a significant change in climate at the end of the Pleistocene (about 10,000 years ago), recolonization of Canada by vegetation proceeded from the refugia and a northward migration of biota from the southern peripheral region of glaciation. The late glacial episode differed from any subsequent Holocene time episode in terms of the availablility of large areas of "raw" soils, the very large volume of meltwater runoff, and the presence of numerous large glacial lakes that at least locally affected the climate.

The main sources of information about late Wisconsin and Holocene vegetation are records of plant macrofossils and fossil pollen and spore assemblages preserved in lake sediments, peat bogs, and alluvial deposits.

Genetic mixing occurred during recolonization when the populations from different refugia met after having been isolated for several thousand years.

The studies of the fossil record are seriously hindered by the lack of basic palynological data (pollen deposition and dispersal in relation to the modern vegetation) and the ecology, phytogeography, and genetics of Canadian vegetation and flora, as well as the relationships between vegetation and climate in particular.

It has been demonstrated clearly that the palynological and paleobotanical studies can provide the necessary information required for construction of paleoclimatological models that can be beneficially used in the study of environmental changes.

A.A.

823. TERASMAE, J. 1974. Deglaciation of Port Hood Island, Nova Scotia. Canadian Journal of Earth Sciences 11(10):1357-1365.

A palynological study and radiocarbon dating of surficial deposits on Port Hood Island, Nova Scotia, have indicated that deglaciation occurred more than 11 000 yr B.P., and that the presence of an 'upper till' in local depressions is attributable to soil - creep processes under cold and wet climatic conditions some 11 000 to 10 000 yr B.P. No evidence was found of an ice advance younger than 11 000 yr B.P. in western Cape Breton Island.

A.A.

824. TERASMAE, J. 1974. An evaluation of methods used for reconstruction of Quaternary environments. In: Quaternary Environments. Edited by: W.C. Mahaney. Geographical Monographs No. 5:5-32.

The methods for study and reconstruction of Quaternary environments (paleobotany and palynology, invertebrate and vertebrate paleontology, climatology, hydrology, glaciology, geomorphic processes, stratigraphy of Quaternary deposits, pedology, sediments, oxygen isotope ratios, archaeology, sea level and lake level changes, biogeography, permafrost features, airfall deposits, tree-rings and varves, petrology of peat, and historical records) can be subdivided into two main categories: those that provide primarily qualitative information, and others that yield quantitative data on environmental conditions and changes.

It has been possible to establish a chronological sequence of Late-Quaternary environmental changes in most of the major geographical regions in Canada. Correlation of these chronologies within each of the regions is relatively easy and between widely separated regions (more than 1,500 km apart) rather more difficult on the basis of limited available data.

The early Holocene biostratigraphic zone boundaries are commonly time-transgressive owing to the progress of deglaciation, and the same kind of environmental change may be indicated in the different regions by fossil assemblages composed of different species because of differences in the past and present specific composition of vegetation and fauna. Therefore, the correlation of Quaternary environmental changes between the different regions must be based on some absolute geochronometric method such as the radiocarbon dating, or dendrochronology.

The established sequence of Quaternary environmental changes, coupled with geochronometric studies seems to provide a base for the construction and 'calibration' of paleoclimatological models that can be used to forecast probable environmental changes in the future.

A.A.

825. TERASMAE, J. 1975. Notes on climatic change, environment and man. In: Environmental Change. Edited by: J.G. Ogden, III and M.J. Harvey. Proceedings of the Nova Scotian Institute of Science 27(Supplement 3):17-36.

A general survey of the evidence for climatic change, including discussion of the North American climate of today and at 12 000 BP. We must be careful that we do not aid the climate to revert to a less favourable earlier state.

G.A.

826. TERASMAE, J. 1976. In search of a palynological tundra. Geoscience and Man 15:77-82.

Pollen assemblages from surface samples of lake-bottom sediment and northern muskeg indicate that the major vegetation regions (boreal forest, taiga, forest-tundra, and tundra) that extend from central Quebec to the eastern Arctic can be identified on the basis of palynological information. Although it is possible to recognize modern palynological tundra in relation to present distribution limits of vegetation, it should not be concluded that unqualified identification can be made of "palaeo-tundra" that presumably existed in the periglacial zone that bordered the southern margin of the continental ice sheet in late Pleistocene time. Our present data base is not adequate with respect to arctic palynological surface sample coverage and the understanding of atmospheric pollen dispersal over the northern regions. This information is required for the study of the history of tundra environment in the Cenozoic palynostratigraphic record.

A.A.

827. TERASMAE, J. 1977. Postglacial history of Canadian muskeg. In: Muskeg and the Northern Environment in Canada. Edited by: N.W. Radforth and C.O. Brawner. University of Toronto Press, Toronto. pp. 9-30.

The author deals with the question of how, when and from where all this muskeg arose. Development of muskeg with deglaciation is briefly reviewed; a description of the muskeg as an ecosystem and a discussion of postglacial climatic changes and muskeg are presented. He also gives a regional history of muskeg development.

L.G.

828. TERASMAE, J. 1980. Some problems of late Wisconsin history and geochronology in southeastern Ontario. Canadian Journal of Earth Sciences 17(3):361-381.

Palynological studies and radiocarbon dating of sediments from about 20 lakes and bogs in southeastern Ontario have been used to establish a palynostratigraphic sequence of six pollen zones extending to approximately 12000 years BP and indicating that deglaciation occurred between 12500 and 11500 years BP, probably during the Two Creeks interstadial interval.

The glacial Lake Iroquois existed in the Lake Ontario basin from about 12500 - 11800 years BP while the Lake Ontario ice lobe was retreating northeastward, and the Kirkfield - Fenelon Falls outlet from glacial Lake Algonquin (in the Georgian Bay - Lake Huron basin) to Lake Iroquois opened about 12000 years ago when the Dummer Moraine was deposited as a stagnant ice disintegration feature south of the Algonquin and Haliburton Highlands.

Most radiocarbon dates (about 25) on marine shells, whale bone, and algae from Champlain Sea beach deposits are in the range of 10000 - 11800 years BP, indicating that the Champlain Sea episode is younger than glacial Lake Iroquois. However, a few Champlain Sea dates are older than 12000 years BP and present an unresolved problem in geochronological correlation because they conflict with proposed deglaciation histories in southeastern Ontario.

Late Wisconsin ice marginal positions are poorly known in southeastern Ontario and comprise another problem for further study.

The end of glacial Lake Algonquin phase (the main drainage event in the North Bay area) probably occurred between 10800 and 10500 years BP, after the Champlain Sea had reached its maximum western limit in the Pembroke area (upper Ottawa River valley) as indicated by stratigraphic relationships of surficial deposits.

A.A.

829. TERASMAE, J., and T.W. ANDERSON. 1970. Hypsithermal range extension of white pine (*Pinus strobus* L.) in Quebec, Canada. Canadian Journal of Earth Sciences 7(2):406-413.

Fossil wood, cones, and leaves of white pine (*P. strobus* L.) were discovered at Val St. Gilles, Quebec, some 60 miles (~ 96.6 km) north of the present distribution limit of this species. The fossils were buried under several feet of peat, and were dated at 5030 ± 130 (GSC-585) radiocarbon years before present. In the pollen diagram from this peat exposure a white pine pollen maximum coincides with the stratigraphic unit in which the fossil pine wood was found. This discovery indicates that white pine was growing well north of its present distribution limit during the Holocene hypsithermal interval, when climatic conditions were more favorable in this region than at present.

A.A.

830. TERASMAE, J., and B.G. CRAIG. 1958. Discovery of fossil *Ceratophyllum demersum* L. in Northwest Territories, Canada. Canadian Journal of Botany 36(5):567-569.

Fossil *Ceratophyllum demersum* L. was discovered on sites east of Great Slave Lake Northwest Territories, Canada. This distribution is both north and east of its presently known range. The palynological evidence supports the conclusion that the climate was warmer than the present when the silt, in which the fossil plant remains were found, was deposited. A radiocarbon age of 5400 ± 230 years (L-428) has been obtained for the sample.

A.A.

831. TERASMAE, J., and J.G. FYLES. 1959. Palaeobotanical study of late-glacial deposits from Vancouver Island, British Columbia. Canadian Journal of Botany 37(5):815-817.

Plant-bearing beds have been discovered by J.G. Fyles in late-glacial deposits from the Englishman River section, Vancouver Island, B.C. Radiocarbon dating indicated an age of ca. 12,000 years for these beds. Fossil cones of *Pinus contorta* Dougl. and leaves of *Dryas drummondii* Richards were discovered and identified. Palynological study indicates that climate at the time was colder than the present.

A.A.

832. TERASMAE, J., and O.L. HUGHES. 1960. Glacial retreat in the North Bay area, Ontario. Science 131(3411):1444-1446.

Geological and palynological studies in Ontario and Quebec, supported by radiocarbon dates, suggest that the opening of the North Bay outlet and the initiation of the Stanley-Chippewa stages in the Huron and Michigan basins took place 10,000 to 11,000 years ago.

A.A.

833. TERASMAE, J., and O.L. HUGHES. 1960. A palynological and geological study of Pleistocene deposits in the James Bay Lowlands, Ontario (42 N½). Geological Survey of Canada Bulletin 62:1-15.

Stratigraphic studies of Pleistocene deposits in the James Bay Lowlands have shown that the sequence begins with glacial deposits overlying bedrock. This part of the sequence consists of two members, the lower drift and the middle drift. These glacial deposits are overlain by layers of peat, silt and clay, here named the Missinaibi beds, which in turn are overlain by glacial deposits of the main Wisconsin glaciation. Marine clay, commonly fossiliferous, overlies the upper glacial drift and is overlain by post-glacial fluvial, lacustrine, and organic deposits.

Palynological studies have been made of both the Missinaibi beds and the post-glacial deposits. Vegetation during the deposition of the Missinaibi beds was similar to that present now in the James Bay Lowlands. On basis of palynological evidence an interstadial rank is proposed for the Missinaibi beds, and radiocarbon dating suggests an age of 55,000 to 64,000 years.

A.A.

834. TERASMAE, J., and O.L. HUGHES. 1966. Late-Wisconsinan chronology and history of vegetation in the Ogilvie Mountains, Yukon Territory, Canada. Paleobotanist 15(1-2):235-242.

Studies of Pleistocene geology and history in the western Ogilvie Mountains, bordering on the east of the unglaciated region in Yukon, were made by Hughes who has recognized three major glacial episodes characterized by successive advances and retreats of valley glaciers originating in cirques along the axis of the southern Ogilvie Ranges. Palynological studies and radiocarbon dating have been used to support and confirm the chronology of complex moraine sequence. The youngest of these glacial episodes is believed to have culminated prior to 10,000-12,900 years ago.

The history of late Wisconsinan vegetation in this area, as inferred from palynological and paleobotanical studies, holds special interest because of the postulated survival of plants in the adjacent unglaciated area which provided a potential late-glacial dispersal centre in addition to migrations reaching the area later from the southeast and south. It seems that birch, alder, willow and spruce were among the early pioneers from the western source. A mixing of the western and eastern floral elements after deglaciation is an interesting problem. The magnitude of the postglacial climatic changes appears to have been smaller than in the more southerly regions. At several sites studied, the onset of the permafrost regime has been an important factor in the development of vegetation, because of its influence on both the groundwater conditions and soil development.

A.A.

835. TERASMAE, J., and P. LASALLE. 1968. Notes on late-glacial palynology and geochronology at St. Hilaire, Quebec. Canadian Journal of Earth Sciences 5(2):249-257.

A palynological study supported by radiocarbon dates of late-glacial sediments at St. Hilaire, Quebec, indicates that the southern part of the St. Lawrence Lowland was deglaciated prior to 12 500 years B.P. The late-glacial episode comprises several climatic fluctuations: a probable early cool interval (northern boreal) more than 12 500 years B.P.; a relatively colder interval (tundra) about 12 500 years B.P., followed by another cool interval from about 12 000 years B.P. to about 10 000 years ago. Another relatively cold episode may have occurred about 11 000 years ago. The new studies extend the previously available palynological record in the St. Lawrence Lowland back in time by about 2 000 years and include the Champlain Sea episode.

A.A.

836. TERASMAE, J., and R.J. MOTT. 1964. Pollen deposition in lakes and bogs near Ottawa, Canada. Canadian Journal of Botany 42(10):1355-1363.

A palynological study of surface samples of lake deposits and peat in the Ottawa area has indicated that pollen and spore assemblages obtained from these samples reflect both the local vegetation and the regional one characteristic of the Great Lakes-St. Lawrence Forest Region. Palynological differences between the upland sites and those of the clay plain of the Ottawa Valley are sufficient to identify these environments. Results of this study will help to strengthen the interpretation based on fossil pollen and spore assemblages found in postglacial deposits, when past environments are inferred from these fossil assemblages.

A.A.

837. TERASMAE, J., and R.J. MOTT. 1971. Postglacial history and palynology of Sable Island, Nova Scotia. Geoscience and Man 3:17-28.

Sable Island holds especial interest in postglacial palynology because it lies about 180 miles east of Halifax, Nova Scotia, near the edge of the continental shelf and is the only emerged part left of an extensive archipelago which existed on the shelf during the last glaciation. A series of buried soil and peat horizons, ranging in age from about 200 to 11,000 radiocarbon years, has been studied palynologically in addition to surface samples and atmospheric pollen deposition. This study has failed to substantiate the claimed presence of interglacial surfaces (soils) on the island and supports instead the hypothesis of a continuously changing and slowly eastwardly migrating complex of sand deposits. The absence of trees on the island facilitates studies on long distance atmospheric transport of pollen and spores from the mainland...

A.A.

838. TERASMAE, J., P.J. WEBBER, and J.T. ANDREWS. 1966. A study of late-Quaternary plant-bearing beds in north-central Baffin Island, Canada. Arctic 19(4):296-318.

Buried plant-bearing beds along Isortoq River at the northern end of Barnes Ice Cap on Baffin Island have been dated at more than 38,830 and 40,000 years B.P. A palynological and palaeobotanical study has indicated the presence of species (e.g. dwarf birch) which now occur several hundred kilometres south of this locality. Because of the inferred climatic conditions, more favourable than the present, an interglacial age (Sangamon) is assigned to the Isortoq plant-bearing beds. Folding of the Isotorq beds by overriding ice and the orientation of the overturned folds indicate accumulation of the initial ice cap east of this locality.

July temperatures were probably between 7 and 10°C that is, about 1 to 4°C higher than the present. Total precipitation may have been 38 cm a year which would represent an increase of 12.7 cm, and the growing season may have been 20-25 days longer, that is, a total length of about 120 days.

A.A.+

839. TERASMAE, J., and N.C. WEEKS. 1979. Natural fires as an index of paleoclimate. Canadian Field-Naturalist 93(2):116-125.

The charcoal abundance and frequency of occurrence varies stratigraphically in postglacial lake sediments, and this information can be used together with palynological and sedimentological data for a reconstruction of paleoclimatic conditions. The gelatin-coated slides method can be used for continuous sampling of lake sediment cores to determine the presence of charcoal particles. Changes in the charcoal profile have been related to changes in the sequence of fossil pollen, specifically that of pine pollen, and from the observed relationship a climatic control of forest fires is inferred. Forest fires have occurred naturally in the Great Lakes-St. Lawrence and Boreal forest regions during the past 9000 years, and the fire frequency almost doubled during the Pine Pollen Zone about 7000 to 4000 years ago in the southern Boreal forest. The mean fire frequency in the Lac Louis area was one fire every 95 to 100 years, but during the period characterized by a pine pollen maximum, 7280 ± 240 yr BP (GSC-1481) to 4260 ± 240 yr BP (GSC-1491), the fire frequency increased to one fire every 48 to 56 years.

A.A.

840. THOMAS, M.K. 1955. Climatic trends along the Atlantic coast of Canada. Transactions of the Royal Society of Canada, Series 3, 49:15-21.

Temperature data from the coastal areas of Nova Scotia and Newfoundland indicate a warming trend during the past sixty-five years. Decadal means of annual and winter temperatures are currently at their maximum for that period and show increases of 2 and 4 degrees respectively during the past thirty years. Although summer temperatures were at their maximum in the early 1930s they are now averaging almost 2 degrees higher than just prior to 1920. The warming trend is evident at Resolution Island, but is not nearly so pronounced. Trends along the Labrador and Baffin Island coasts are probably similar to those at Resolution Island and these stations show greater year to year variation than those on the southeastern coast of Canada.

A.S.

841. THOMAS, M.K. 1957. Changes in the climate of Ontario. In: Changes in the Fauna of Ontario. Royal Ontario Museum, University of Toronto. pp. 57-75.

Prior to the Pleistocene Ice Age, Ontario had climates peculiar to the different geological ages. Climates warmer than today's existed some 90% of the time, and we are today only in the warming up phase of this recent ice age. The warmest climates since the ice retreated from Ontario was probably during the climatic optimum some six thousand years ago. All evidence indicates that there have been no major changes in our climate during the Christian era.

Instrumental climatic data are available from Toronto since 1840 and from other places in Ontario since 1870. There has been a definite increase in temperature during this time, and at Toronto it amounts to about three degrees Fahrenheit per century when the artificial "city effect" is discounted. Evidence indicates that this rate, which has not been steady, is common over southern Ontario, but in northern Ontario it may be less. The trend in precipitation including snowfall is towards smaller annual amounts. The decrease at Toronto is between three and four inches over a century, occurring mostly in the autumn and winter seasons. Since the last few decades of the past century, precipitation over southern Ontario has decreased by about one inch. Taking into consideration the variation in precipitation from year to year, this precipitation trend is not considered to be as significant as the temperature trend towards warmer values.

Thomas

842. THOMAS, M.K. 1960. Canadian Arctic temperatures. Department of Transport, Meteorological Branch, CIR.-3334, CLI.-24:1-38.

In the sub-Arctic records from Dawson and Fairbanks a warming trend from the 1910s to the early 1930s is revealed and further warming in the 1940s. In this continental area the trend during the 1950s has been towards lower temperatures. An entirely different trend has been observed on the western Arctic coast and is illustrated by data from Barrow and Aklavik. Along the coast there have not been any marked climatic fluctuations since the beginning observations in the 1920s. In the eastern Arctic, records from Arctic Bay and nearby Pond Inlet date back to the 1920s and this area has shown a warm up similar to the one at Dawson in the 1940s with a subsequent though not as marked, cooling off period during the 1950s...

Thomas

843. THOMAS, M.K. 1961. A bibliography of Canadian climate 1763-1957. Meteorological Branch, Department of Transport. Division of Building Research, National Research Council, Ottawa. 114 pp.

A chronological bibliography of Canadian climate. Subject and geographical, author, and reference indexes are provided. Approximately 1300 references listed by year.

A.B.S.

844. **THOMAS, M.K. 1973. References to meteorological studies of climatic fluctuations in Canada published during the period 1970-January 1973. Atmospheric Environment Service, DS 4-73:1-3.**

Eighteen references, listed by year.

A.B.S.

845. **THOMAS, M.K. 1973. A bibliography of Canadian climate 1958-1971. Atmospheric Environment Service. Environment Canada, Ottawa. 170 pp.**

A chronological bibliography of Canadian climate. Subject and geographical, author, and reference indexes, in English and French, are provided. Approximately 1700 references, listed by year.

A.B.S.

846. **THOMAS, M.K. 1974. Canada's climates are changing more rapidly. Canadian Geographical Journal 88(5):32-39.**

With five identifiable climatic provinces and considerable daily fluctuation, longer term variations are difficult to establish. Statistical analysis of data for up to 10 years is usually sufficient to illustrate fluctuations. Likely mechanisms for causing climatic change are discussed as are methods of detecting post-Pleistocene climatic variations. Fluctuations since the mid-19th century are described together with spatial variations but prediction with accuracy is viewed as unlikely.

G.A.

847. **THOMAS, M.K. 1975. Meteorological studies of climatic fluctuations in Canada, 1917-1960. An annotated bibliography. Atmospheric Environment Service DS 7-75:1-9.**

Twenty-six annotations, in both English and French, are provided.

A.B.S.

848. **THOMAS, M.K. 1975. Recent climatic fluctuations in Canada. Environment Canada. Atmospheric Environment Service, Climatological Studies 28:1-92.**

Discusses climatic variations over the past third of a century. Contents includes data on such parameters as temperature, precipitation, bright sunshine, cloudiness, snowfall, and pressure in a regional context. For purpose of this study, Canada is divided into 11 climatic districts.

L.G.

849. **THOMAS, M.K. 1981. Towards a Canadian climate program. In: Climate Change Seminar Proceedings, Regina. March 17-19. Canadian Climate Centre, Downsview. pp. 86-90.**

"Climate is a vital component of Canada's natural environment and its anomalies or variations, regardless of any long term trends, have marked socio-economic effects. The past year or so has provided several examples. During the 1979-80 winter, only one third to one half of normal snowfall occurred in the heavily populated region stretching from Windsor to Quebec City and the result was a disastrous season for winter outdoor recreation businesses, although millions of dollars were saved in snow removal costs. Drought has been a worry in the Prairies where a shortage of surface water supplies still exists. A very costly aspect of the drought in 1980 was the record number of forest fires in Ontario and the Western Provinces. Monetary loss exceeded a billion dollars in Ontario alone and fire fighting operations cost nearly $200 million across the country. The early winter of 1980-81 produced mudslides and floods in British Columbia, record high heating bills in Eastern Canada and paralyzing snowstorms to areas of the Atlantic Provinces. In mid-winter the abnormally warm conditions in western Canada spread over the east to the dismay of winter sport enthusiasts but to the delight of motorists and most householders."

Such anomalies or variations emphasize the need for a comprehensive climate program. Environment Canada initiated the Canadian Climate Program in 1978. The author outlines the objectives and current status of this program.

A.B.S.

850. THOMAS, M.K., and D.W. PHILLIPS. 1979. A bibliography of Canadian climate 1972-1976. Environment Canada, Atmospheric Environment, Ottawa. 135 pp.

A chronological bibliography of Canadian climate. Subject and geographical, author, and reference indexes, in English and French, are provided. Approximately 1100 references, listed by year.

A.B.S.

851. THOMPSON, P., H.P. SCHWARCZ, and D.C. FORD. 1974. Continental Pleistocene climatic variations from speleothem age and isotopic data. Science 184(4139):893-895.

Speleothems from continental North American caves [considers the southern Canadian Rockies and the Northwest Territories] have been dated by means of the $^{230}Th/^{234}U$ method. Oxygen isotopic variations in the dated samples and phases of speleothem deposition can be interpreted in terms of climatic change. A glacial chronology constructed from the age and isotopic data lends support to the astronomical theory of climatic change.

A.A.$^{+}$

852. THOMSON, A. 1935. Variability of Canadian winters. Journal of the Royal Astronomical Society of Canada 29(4):129-139.

"The winters in Canada east of the Rockies are well known to vary widely in severity from year to year. The temperature records from nine stations for the past 50 years have been analyzed to discover any definite trend towards mild or severe winters in Canada, and the factors are discussed which would tend to produce either cold or mild winters in the various sections of Canada." The author found that in comparing the record for Toronto and Paris, Ontario for the period 1890 to 1930 the difference, (i.e., the urban-rural difference) in temperature, remained almost constant over the period despite a great increase in the population of Toronto. Taking winter as the months of December, January and February, the author cites mean winter temperatures at nine different locations in Canada and classifies the severity of winters in four regions of Canada. The greatest variability is found on the Prairies followed by eastern Canada, then the Maritimes and finally the least variable temperature conditions were found in British Columbia.

Thomas

853. THOMSON, A. 1936. Sunspots and weather forecasting in Canada. Journal of the Royal Astronomical Society of Canada 30(6):215-232.

Precipitation, temperature and cloudiness at stations along the southern border of Canada, and thunderstorms at Toronto may be affected by variations in sunspots, but records extending from 30 to 80 years at these stations are not sufficiently long to show it. Temperatures over the Prairies are possibly slightly lower during years of sunspot maximum, but yearly values in any cycle will show a random scatter about the mean. The temperature and rainfall departure at any station for a particular year of the sunspot cycle varies so irregularly from the mean from one cycle to another, that it is without value to attempt to use the sunspot variation curve for forecasting weather at stations in Canada. Variations in the period and amplitude of sunspot fluctuations are so great that the number of sunspots present a year or so in advance cannot be accurately forecast. Hence, the seasonal weather forecasts based on sunspot numbers are unreliable.

Thomas

854. TUCKER, C.M., and S.B. McCANN. 1980. Quaternary events on the Burin Peninsula, Newfoundland, and the islands of St. Pierre and Miquelon, France. Canadian Journal of Earth Sciences 17(11):1462-1479.

Morphogenetic mapping of surficial deposits and analysis of infrequent multiple-unit exposures of drift in the Burin Peninsula and on St. Pierre and Miquelon provide evidence of the following sequence of late Quaternary events in the south-central coastal region of Newfoundland. (1) Overall glaciation by Newfoundland-centred ice (pre-Wisconsinan or, possibly, Early Wisconsinan in age), represented by a few occurrences of weathered till. (2) Overall glaciation by Newfoundland-centred ice (Early Wisconsinan), widely represented throughout the peninsula. (3) Marine overlap in the southwest of the peninsula and on St. Pierre and Miquelon (Mid-Wisconsinan). (4) Partial glaciation by ice from an offshore source to the southeast (late Mid-Wisconsinan), represented by onshore-directed striae and a well-developed former ice-marginal position in the lower peninsula. (5) Limited glaciation by Newfoundland-centred ice of the northern part of the area (Late-Wisconsinan); the former ice margin is a well-defined feature across the Gisborne basin and small separate ice caps existed along the central spine of the upper peninsula. In developing the chronology for these events, the occurrence of marine deposits, containing Foraminifera of proposed Mid-Wisconsinan age, between two till units at Dantzic Cove in the southwest of the Burin Peninsula is important.

A.A.

855. TULLY, J.P., A.J. DODIMEAD, and S. TABATA. 1960. An anomalous increase of temperature in the ocean off the Pacific Coast of Canada through 1957 and 1958. Journal of the Fisheries Research Board of Canada 17(1):61-80.

The temperature increase extended from the surface to nearly 500 metres depth. Its progress is shown by temperature distribution on the isopycnal surface which is in the haloclyne immediately below the depth of seasonal influence. During this period the current veered northward and strengthened. The spawning migration of sockeye salmon in the ocean was shifted northward and delayed in association with these anomalous oceanographic conditions.

Thomas

856. Understanding Climatic Change A Program for Action. Compiled by: United States Committee for the Global Atmospheric Research Program. National Academy of Sciences, Washington, D.C. 239 pp. 1975.

The first purpose of this report was to advise on the "urgent need for a coherent national research program on the problem of climatic variation". The second purpose was to recommend the steps necessary to address this problem in an international context. Topics considered within the report include: "a discussion of the physical basis of climate and climatic change, a summary of past climatic variations as drawn from the instrumental and paleoclimatic record, a brief review of the scope of present research on climatic variation and the proposed climatic research program".

A.B.S.

857. **VAN RYSWYK, A.L. 1971. Radiocarbon date for a cryoturbated alpine regosol in south central British Columbia. Canadian Journal of Soil Science 51:513-515.**

Charcoal pieces contained in a buried Ah horizon on Lakeview Mountain in south central British Columbia have a radiocarbon age of 9120 ± 540 years B.P. (GSC-1390). This date is used in reconstructing the sequence of events affecting the development of an Alpine Regosol at this site. About 11,500 years ago ice left the area. The climate was warmer and/or wetter than at present by about 9000 years ago, and could support tree or shrub vegetation. The charcoal was produced when this vegetation was destroyed by fire. When the climate became colder and/or drier, tundra-like vegetation dominated and alpine Ah horizons were formed. The Ah charcoal-containing horizon would have been buried later than 9000 years B.P., and possibly later than 6600 years B.P. The evidence does not suggest that cryoturbation has continued to the present.

A.B.S.

858. **VASS, S.E. 1981. Climate change and variability; some implications for Prince Edward Island. In: Climate Change Seminar Proceedings. Regina, March 17-19. Canadian Climate Centre, Downsview. pp. 60-71.**

"The resources and practises most sensitive to climate in Prince Edward Island are agriculture, tourism and recreation, fisheries, transportation, the distribution and demand for energy, wildlife, and planned new departures in forest management. Some climatic effects are direct, some indirect through changes induced in soil and water quality; and though some effects are self-evident others are subtle and often not clearly understood." The author discusses the implications of climate variability on these resources.

A.B.S.

859. **VENKATARANGAN, P. 1978. Influence of solar activity on growing seasons in the Canadian Prairies. Institute of Space and Atmospheric Studies, University of Saskatchewan, Saskatoon. 23 pp.**

New evidence of statistically significant changes in the length of the growing season in the Prairie Provinces is presented to show that a strong connection exists between solar activity and weather. Further, it is demonstrated that the relationship between solar activity and weather exists through solar flares. The length of the growing season is observed to decrease with increasing solar flare activity everywhere in the Prairies. The additional enchancement in the growing season length found near the peak of a sunspot cycle and the strong variations noted during the declining phase of a sunspot cycle lead to our principal interpretative suggestion that energetic solar particles could play a dominant role in the energetics of Sun-weather relationships. Despite the poor understanding of these variations, it is shown that the results have some merits of applicability.

A.A.

860. VIBE, C. 1967. Arctic animals in relation to climatic fluctuations. Meddelelser om Grønland 170(5):7-227.

A study of the East Greenland Ice in Davis Strait makes it possible to recognize three main drift-ice stages which play an important role for climate and ecology in all Greenland.

A) - The drift-ice stagnation stage (approx. 1810-60)

The East Greenland Ice does not advance far north into Davis Strait where the Canadian Current has a dominating influence. The climate of northern West Greenland is relatively cold, dry and stable. The populations of sea mammals and sea birds concentrate at central West Greenland. The winter climate is favourable for the Reindeer in central and northern West Greenland, and the population increases and culminates.

The population of white Arctic Fox increases and culminates in southeastern Canadian Arctic. The white percentage increases in West Greenland. The Cod occurs along the coast of southern West Greenland, but it is not abundant, except for short periods with little drift-ice.

The drift-ice is relatively stable throughout the winter off Northeast Greenland where the climate is favourable for the Reindeer and the Musk Ox. The populations increase.

B) - The drift-ice pulsation stage (approx. 1860-1910)

The ice of the Arctic Ocean drifts into the Atlantic in larger amounts than before. The East Greenland Current and the East Greenland ice advance far north into Davis Strait either early or late in summer. The populations of sea mammals and sea birds decrease in central West Greenland. The climate becomes relatively unstable and wet. The wet winters are unfavourable for the Reindeer in West Greenland and the population decreases.

The population of white Arctic Fox decreases in Canadian Eastern Arctic and that of blue Arctic fox increases in central and northern West Greenland. The white percentage stagnates or decreases in northern West Greenland. Cod occur only occasionally in short periods with early drift-ice in Davis Strait.

The drift-ice moves relatively fast off Northeast Greenland where the population of Musk Ox stagnates owing to wet winters. The Reindeer becomes extinct in Northeast Greenland.

The population of Greenland Whale stagnates in the Atlantic region.

C) - The drift-ice melting stage (approx. 1910-1960?)

The East Greenland Ice decreases in Davis Strait where the Irminger Current has a dominating influence on climate and production. The populations of sea mammals and sea birds increase in northern West Greenland and in East Greenland. The Reindeer population of West Greenland has ample summer grazing, but the winter pastures are often covered by snow and ice - and the population stagnates in all West Greenland, except for the short dry period 1910-20.

The population of white Arctic Fox increases and culminates in all eastern Canadian Arctic and in Northeast Greenland, and that of blue Arctic Fox in all West Greenland. The white percentage decreases in central and increases in northern West Greenland. Cod occur abundantly along the coast of West Greenland and multiply in Greenlandic waters. The population increases in periods with little or early drift-ice and decreases in periods with late drift-ice in Davis Strait.

Northeast Greenland has ample vegetation and the Musk Ox population usually thrives and increases, but is often threatened by catastrophes in wet autumns and winters when Greenland Sea has little or no drift-ice.

At present a new "drift-ice stagnation stage" is beginning (approx. 1960-?).

A.A.

861. VIGDORCHIK, M.E. 1981. Isolation of the Arctic from the global ocean during glaciations. In: Sea Level, Ice, and Climatic Change. Edited by: I. Allison. International Association of Hydrological Sciences 131:303-322.

Most of the Pleistocene marine deposits of northern Eurasia on the Eurasian coast of the Arctic Ocean were formed by "cold" marine transgressions which were synchronous with the early and middle Pleistocene glaciations in northern Eurasia and America (Dneper, Samara, Illinoian). The organic remains associated with these transgressions indicate sea and air temperatures colder than in the Holocene, Boreal (Eemian/Sangamon), and Holstein, Likhvin hypsithermals. This record of Arctic marine transgressions and regressions differs from that of the global ocean. Repeated and widespread "cold" transgressions in northern Eurasia cannot be explained by tectonic activity alone. As an alternative, the author in 1971 proposed the hypothesis of complete isolation of the Arctic Ocean during the glaciations. The key concept of this hypothesis is the formation of isolating barriers in the North Atlantic (Greenland-Iceland-Faeroes-Scotland) as a cumulative result of (a) glacial-eustatic regression of the global ocean; (b) isostatic uplift of peripheral blocks around the glacial shields in a mosaic of plateau basalt sub-oceanic structures in the North Atlantic; (c) glaciation of emerged and semi-emerged areas in this zone. The glacio-isostatic, tectonic and faunistic evidence for the concept of Arctic isolation is discussed.

A.A.

862. VILKS, G. 1974. The distribution of planktonic foraminifera in the sediments and water of the Northwest Passage and northern Baffin Bay: a tool for paleooceanographic synthesis. Geological Survey of Canada Paper 74-30 (Volume 1):109-121.

The distribution of the various phenotypes of *Globorotalia pachyderma* (Ehrenberg) is correlated with oceanographic parameters. Large percentages of small normalform adults were found in the mixed waters of eastern Lancaster Sound. After death 80% of these fragile normalforms are destroyed, leaving the Lancaster Sound sediments almost barren of planktonic foraminifera. The kummerform and quadrate phenotypes that developed under less favourable conditions have thicker test walls and are consequently more readily preserved. It is proposed that the fraction of normalform phenotypes in the sediment cores are useful to interpret paleoenvironments.

A.A.

863. VILKS, G. 1977. Trends in the marine environment of the Canadian Arctic Archipelago during the Holocene. In: Polar Oceans. Edited by: M.J. Dunbar. Arctic Institute of North America, Calgary. pp. 643-653.

Changes in marine paleoenvironment in the Canadian Arctic Archipelago are discussed on the basis of foraminiferal assemblages in bottom sediments. In Lancaster Sound during glacial recession (18,000 - 6,000 years BP), bottom waters were less mobile than at present. In the Northwest Passage the present circulation was established at 6,000 BP. In Prince of Wales Strait during the marine maximum the circulation was in the opposite direction to what it is now. In the northwestern Queen Elizabeth Islands the channels have become shallower during the Holocene, while the extent of summer ice has remained close to that found at present.

A.A.

864. VILKS, G. 1981. Late glacial-postglacial foraminiferal boundary in sediments of Eastern Canada, Denmark and Norway. Geoscience Canada 8(2):48-55.

Sediments in cores collected from the Scotian and Labrador shelves contain a faunal discontinuity where older benthic foraminiferal assemblages dominated by *Elphidium excavatum f. clavata* change to more diverse present day continental shelf assemblages. A similar change is found in Late Quaternary borings in Denmark (Jutland) and in the Oslofjord area of Norway. The ^{14}C age of the faunal break varies from 10,000 years BP in the European sediments to 13,000 years BP on the Scotian Shelf and 15,000 years BP on the Labrador Shelf.

The present day oceanographic setting along the coasts of Norway, Denmark and eastern Canada was established when the glacial ice retreated inland. The dominance of *E. excavatum f. clavata* in the older sediments is related to diluted and cold coastal waters during the time when continental ice was ablating on the inner shelf. The disappearance of *E. excavatum f. clavata* therefore can be used to estimate the Late Glacial-Postglacial boundary in the Canadian and Scandinavian North Atlantic continental shelf sediments. This paper reviews the evidence of the faunal break to alert geologists in its possible use.

A.S.

865. VILKS, G., and P.J. MUDIE. 1978. Early deglaciation of the Labrador Shelf. Science 202(4373):1181-1183.

Two marine sediment cores from a basin on the southeastern Labrador Shelf penetrate a mud sequence extending back to 21,000 carbon-14 years before the present (B.P.). The benthic foraminifera are dominated by subarctic nearshore species indicative of ice-free summer waters. The pollen record indicates the presence of a sedge-shrub tundra in eastern Labrador as early as 21,000 years B.P. Both sources of evidence suggest less extensive continental ice than has previously been reported for this subarctic region.

A.A.

866. VINCENT, J.-S. 1973. A palynological study for the Little Clay Belt, northwestern Québec. Naturaliste Canadien 100(1):59-70.

Little information is available on the postglacial geochronology, vegetation and paleoclimates of the Clay Belt of northwestern Québec and northeastern Ontario. Based on the analysis of a sediment core recovered from Lake Louis, Laverlochère Township, Témiscamingue County, Québec, a pollen stratigraphy for the Little Clay Belt is presented.

Six stratigraphic pollen zones determined for the Lake Louis site are correlated with other pollen zones of central Quebec and the St. Lawrence Lowlands. After the initial warm period that followed deglaciation and the partial drainage of Lake Barlow-Ojibway, a colder, moist period existed. This was followed by the two distinct periods of the hypsithermal interval in which the later period is warmer and drier. The hypsithermal was followed by a warm but moist climate, and then later on by the present cooler, moist climate.

The first vegetation colonized the Lake Louis site 9,090 ± 240 B.P. years ago (GSC-1432). A radiocarbon age determination at the boundary between the two periods of the hypsithermal gave a date of 7,280 ± 250 B.P. (GSC-1481). This dates the shift in vegetation from jack-pine to white and red pine, which indicates the continuing warming trend of the climate during that period. Another C-14 age determination at the end of the hypsithermal gave a date of 4,260 ± 240 B.P. (GSC-1491). At this time, the warm climate had already started to deteriorate in the area. The "Cochrane Surge" probably occurred at the end of the colder, moist period that followed the initial warm period.

A.A.

867. VINCENT, J.S. 1978. Limits of ice advance, glacial lakes, and marine transgressions on Banks Island, District of Franklin; a preliminary interpretation. Geological Survey of Canada Paper 78-1C:53-62.

Three glaciations with associated marine and glaciolacustrine phases on Banks Island are recognized for the first time. The oldest (Banks Glaciation) affected all but the northwest part of the island; glacial lakes Egina and Storkerson were formed during deglaciation. Ice of the Thomsen Glaciation of pre-Sangamonian age covered the south and east and flowed down

Thomsen River valley. Associated with it are glacial lakes Parker and Dissection in the northeast and a marine transgression, the Big Sea, which followed the ice during deglaciation and inundated much of western, central, and eastern Banks Island. The youngest, or Amundsen Glaciation, of probable Early or Middle Wisconsinan age involved two icelobes that impinged in the east and southwest coasts creating glacial lakes Raddi, Masik, Rufus, De Salis, Cardwell, and Sarfarssuk at their limit. Ice of the Viscount Melville Glaciation, possibly equivalent to the Amundsen Glaciation and probably also of Wisconsinan age, impinged on the north coast and created glacial lakes Ballast and Ivitaruk. The East Coast Submergence, which inundated the east coast up to 120 m, may be equivalent to the Meek Point Sea that covered the west up to 20 m; both possibly relate to Early or Middle Wisconsinan deglaciation. The Schuyter Point Sea of Late Wisconsinan-Holocene age drowned the east coast up to 25 m and is possibly a transgression that occurred in an icefree area. Sand Hills Readvance in Thesiger Bay and Russell Readvance on the northeast coast are possibly late readvances of Amundsen and Viscount Melville ice, respectively.

A.A.

868. VINES, R.G. 1977. Possible relationships between rainfall, crop yields and the sunspot cycle. Journal of the Australian Institute of Agricultural Science 43(1-2):3-13.

Research overseas has shown a possible relationship between sunspots and long-term weather variations in different parts of the world. Indeed, it has been pointed out that crop production in both the northern and southern hemispheres seems geared in some way to the solar cycle, although the connection with sunspot activity is complex.

A study has therefore been made of crop production in both southeastern Australia and the Canadian Prairies, and the influence of rainfall upon the yield of non-irrigated crops, (such as wheat, oats, barley and hay), has been examined. Quasi-periodic variations are observed in the yields of these crops, reflecting similar long-term fluctuations in rainfall which are possibly associated with changes in solar activity.

A computer technique using past rainfall records as data has been employed to analyse long-term rainfall trends. The results of the analysis are consistent with the observed 'cyclic' pattern of crop yields, and also with the incidence of disastrous forest fires in both Canada and Australia, which are, of course, promoted in drought conditions. The implication is that major droughts are determined by weather patterns which are distinctive of the areas concerned, and a study of these patterns does suggest certain connections with the sunspot cycle.

A.S.

869. VOWINCKEL, E., and S. ORVIG. 1967. Climatic change over the polar ocean. I. The radiation budget. Archiv für Meteorologie, Geophysik und Bioklimatologie, Serie B, 15(1-2):1-23.

Climatic change results from changes in the terms of the energy equation. The present study consists of an analysis of possible changes in the radiative terms of the Polar Ocean energy budget.

The absorbed global radiation at the surface depends mainly on clouds and surface albedo. These factors are discussed, and the absorbed global radiation is presented for various extreme surface and atmospheric conditions.

The short wave radiation absorbed in the atmosphere is next discussed. It is apparent that variations in the atmospheric short wave absorption are of rather small importance for climatic change.

There is greater possibility of variations in long wave radiation than of solar radiation. Theoretical polar atmospheres are discussed, with the consequent changes in the radiation balance. The conclusion appears that the atmosphere is at present adjusted in the best possible way for the conservation of energy.

Long wave fluxes have been calculated for the condition of an open Polar Ocean in winter and for a Polar Ocean completely frozen throughout the year.

It is concluded that, for cloudless conditions, there is little possibility for change in the long wave balance in summer; the long wave balance would become much more negative in winter; the development of a winter balance less negative than the present seems unlikely. Changes in surface conditions are much more important than changes in the atmosphere, for the long wave radiation budget.

Various radiation budgets are presented, for different assumed conditions. The optimum surface conditions would occur with winter overcast and summer cloudless sky. The annual radiation balances would become:

With present Polar Ocean surface:	+ 23.9Kcal cm^{-2}
With frozen surface:	+ 3.3Kcal cm^{-2}
With open ocean:	+ 47.1Kcal cm^{-2}

The earth-atmosphere radiation budget is presented for an open Polar Ocean with cloud conditions such as presently found over the Norwegian Sea. It is apparent that the Polar Ocean is at present in a delicate radiational balance, and relatively minor variations in any term can result in a process leading to complete freeze-over or to complete melting.

The atmospheric heat advection required with an open Polar Ocean would decrease significantly. In winter, it is even possible that this term in the energy budget might become negative (heat export from the Polar Ocean).

A.S.

870. **VOWINCKEL, E., and S. ORVIG. 1969. Climatic change over the polar ocean. II. A method for calculating synoptic energy budgets. Archiv für Meteorologie, Geophysik and Bioklimatologie, Serie B, 17:121-146.**

The objective of this method is to obtain numerical values for all terms in the heat balance equations for the atmosphere and the earth's surface. The method is to calculate complete energy budgets using synoptic data. Once a certain number of circulation types have been investigated, over different regions, it may become possible to discuss the influence of particular synoptic events on the climate and general circulation. The model can be used for grid points, or for single stations, or for geographical areas.

A.S.

871. **VOWINCKEL, E., and S. ORVIG. 1969.** Climatic **change over the polar ocean. III. The energy budget of an Atlantic cyclone. Archiv für Meteorologie, Geophysik and Bioklimatologie, Serie B, 17:147-174.**

The heat budget of a deep stationary January Low in the North Atlantic is studied, together with those of a series of peripheral Lows moving around it. The atmospheric and surface budgets are calculated from synoptic data. The system accomplished heat accumulation in its northern part and a decrease in heat storage in the Southwest sector. This was made possible by the effect of the turbulent terms in transporting heat from the ocean.

A.S.

872. **WAGNER, F.J.E. 1970. Faunas of the Pleistocene Champlain Sea. Geological Survey of Canada Bulletin 181:1-104.**

The Champlain Sea was a body of water of varying salinity that covered parts of the present Ottawa - St. Lawrence Lowland from about 11,500 years B.P. to between 8,000 and 9,000 years B.P. Fossils are widespread throughout the area and have been the subject of numerous studies since 1837. A comprehensive listing of previous records has been issued separately, and this report presents the results of more recent field work. Species examined by the writer are described and illustrated.

The faunal assemblages indicate that the Champlain Sea was shallow, with the salinity of the water ranging from almost fresh in the upper reaches of the Ottawa River and Lake Champlain areas of inundation, to more nearly marine in the Quebec City area. Water temperatures were boreal in the earlier stages of the sea and later became more temperate. An attempt to establish precise temperatures by O^{18} isotope determinations was not successful.

A.A

873. WAGNER, F.J.E. 1970. Palaeoecology of marine Pleistocene Mollusca, Nova Scotia. Canadian Journal of Earth Sciences 14(6):1305-1323.

Fossiliferous Pleistocene sediments are present in western mainland Nova Scotia and on Cape Breton Island. Two ages of deposits are represented: post-glacial in the Minas Basin area and mid-Wisconsinan in the Yarmouth-Digby area and Cape Breton. The mid-Wisconsinan age is based on both radiocarbon and U-Th dates. Molluscan assemblages indicate water temperatures colder than at present at the time of deposition of the post-glacial sediments, and comparable to the present for the older deposits. Assemblages from the Yarmouth-Digby area are compared with those of similar age from Tobaccolot Bay, Long Island, New York, and from Nantucket Island, Massachusetts. Foraminifera, previously unreported, were found in sediments of both ages.

A.A.

874. WAHL, E.W., and R.A. BRYSON. 1975. Recent changes in Atlantic surface temperatures. Nature 254(5495):45-46.

Presents a fuller analysis of data on North Atlantic temperature changes over the past 20 years reported by Rodewald. It seems that the considerable changes are well-based for they depend largely on weather-ship data. The 1951-72 shift seems to mark a return to the Little Ice Age conditions, and to amount to about one-sixth of the shift to full glacial conditions. The core of decreasing temperature lies along the north edge of the North Atlantic drift east of the Maritimes (45 degrees N) and suggests replacement by the Labrador Current, especially in the vicinity of the Grand Banks.

G.A.

875. WALSH, J.E., and C.M. JOHNSON. 1979. Interannual atmospheric variability and associated fluctuations in arctic sea ice extent. Journal of Geophysical Research 84(C11):6915-6928.

Observational data are used to evaluate quantitatively the relationships between arctic sea ice extent and the high-latitude atmospheric circulation on the seasonal time scale. The sea ice data set contains 300 monthly grids of observed sea ice concentrations. The atmospheric variables include sea level pressure, surface temperature, 700-mbar height, and 700-mbar temperature. Statistically significant correlations between the dominant modes of atmospheric and sea ice variability are found at atmospheric lags of up to 2 months and ice lags of up to 4 months. The surface temperature field generally shows the strongest relationship to the sea ice fluctuations. The strongest correlations between ice anomalies and subsequent atmospheric fluctuations are found in the autumn months of increasing ice extent. Evidence of sea-atmosphere coupling is also found in the mid-latitude fields of the North Atlantic. The meteorological difference fields derived from years of extreme ice extent contain statistically significant pressure differences of up to 10-15 mbar, surface temperature differences of up to 8° - 9°K, and 700-mbar height differences of up to 16-18 decameters. The anomaly centres tend to migrate seasonally with the ice edge. The statistical predictability of large-scale sea ice fluctuations decays to the level of no skill at a forecast interval of 5-6 months.

A.A.

876. WEBB, T., III. 1980. The reconstruction of climatic sequences from botanical data. Journal of Interdisciplinary History 10(4):749-772.

"The temporal sequences of botanical data, ranging from time scales of hundreds of millions down to tens of years, are a rich source of information about past climates". A review of the calibration of botanical data in climatic terms is illustrated by two examples, both from the United States.

A.B.S.

877. WEBB, T., III. 1981. Northern hemisphere climatic patterns 5000-7000 years ago: status report. First Conference on Climate Variations of the American Meteorological Society, January 19-23, San Diego. Abstracts, p. 25.

Estimates of global ice-volume from deep sea cores for 6000 years ago indicate a minimum of ice and thus a maximum contrast from full glacial conditions 18,000 years ago. Mapping the climatic patterns for this "glacial minimum" world will permit comparisons to show the extreme climatic contrasts in a glacial/interglacial cycle and will also help in estimating how much current climatic patterns differ from those of mid-interglacial time. The most current maps will be described that show patterns derived from pollen, lake-level, and foraminifera data from North America, the North Atlantic, Europe, the Soviet Union, and North Africa.

A.A.

878. WEBB, T., III, and J.H. McANDREWS. 1976. Corresponding patterns of contemporary pollen and vegetation in central North America. Geological Society of America Memoir 145:267-299.

Use of modern pollen spectra as a basis for interpreting diagrams of fossil spectra requires compilation of the modern spectra in readily accessible form, such as contoured maps of percentage values of individual pollen types. Maps are presented that show the distribution of modern pollen based on 606 samples from central North America (lat 35°N to 70°N, long 75°W to 110°W). Only data published after 1960 are included, and data from 69 sites are presented for the first time. The maps show differences in the pollen percentages among vegetational regions. For example, peak pollen values of Cyperaceae and *Betula* occur in the tundra; high values of *Picea* appear in the northern boreal forest; high values of *Pinus* appear in the southern boreal forest and the adjacent conifer-hardwood forest; high values of *Tsuga*, *Fagus*, and *Acer* occur eastward in the conifer-hardwood forest; high values of *Quercus*, *Ambrosia*, *Fraxinus*, and *Carya* occur in the deciduous forest; and high values of nontree pollen (Gramineae, *Artemisia*, Chenopodiineae, and Compositae) appear in the prairie.

Trend-surface analysis and principal components analysis summarize the regional trends of each pollen type and illustrate the patterns of covarying pollen types within the data. Although these data provide a basis for interpreting the major fossil pollen zones for Holocene time in central North America, additional sampling and more detailed examination of the data are required for description of the fine-scale changes within fossil zones.

A.A.

879. WENDLAND, W.M., and R.A. BRYSON. 1970. Atmospheric dustiness, man, and climatic change. Biological Conservation 2(2):125-128.

During the past century the world's mean temperature generally rose at least until the early 1940s, since when it has decreased. Three primary reasons for these trends have been hypothesized by various authors, namely, rising concentrations of atmospheric carbon dioxide brought about by the burning of fossil fuels, sunspot number variations, and dust injected into the atmosphere by volcanic eruptions. Although each of the above can explain short-term temperature trends, they cannot, singly, explain the entire record. The few observations for atmospheric dust concentrations that exist suggest that a catastrophic rise in concentration since the 1930s, due to human activities, may have overcome the warming trend prior to 1940 and caused the subsequent decrease in world mean temperature. The conservational implications of climatic charge may be enormous - especially in terms of biogeography and biological productivity.

A.A.

880. WENDLAND, W.M., and R.A. BRYSON. 1974. Dating climatic episodes of the Holocene. Quaternary Research 4(1):9-24.

Monitoring evidence indicates that the Holocene embraced a sequence of rather discrete climatic episodes. The transitions between these environmental episodes apparently were abrupt and globally synchronous. This paper reports on statistical analyses of radiocarbon dates associated with environmental change and cultural change.

Over 800 ^{14}C dates associated with pollen maxima and minima, sea level maxima and minima, and top and bottom surfaces of peat beds were simultaneously analyzed to identify times of globally synchronous environmental discontinuities.

Some 3700 ^{14}C dates associated with 155 cultural continua of the world were collectively analyzed to identify worldwide synchroneities in appearance and termination of the cultures.

Significant globally synchronous discontinuities were identified in each independent analysis. The dates of environmental and cultural discontinuities are rather similar, particularly during the recent half of the Holocene. The fact that the cultural discontinuities mostly follow rather closely those of the paleobotanical record suggests that there has been a distinct climatic impact on the cultural history of man.

A.A.

881. WENNER, C.G. 1947. Pollen diagrams from Labrador. Geografiska Annaler 29:137-373.

In the east of the U.S.A. and the south-east of Canada, the tree limits of the temperate areas have moved northwards in the same way as can be proved in Europe during a postglacial warm period.

In Finnish Lappland and Petsamo the northern limit of the conifer forest has moved northwards before subatlantic time, and during the same period the pine limit in the Scandinavian mountain chain was a hundred meters or so higher than at the present time. Along the east coast of Labrador it has not been possible to prove any major movement of the conifer forest limit towards the barren region. Judging by the pollen diagrams the principal effect of the postglacial warm period in Labrador has been to enhance the forests in the boundary region between the forest and the barren region.

During the warm period it is possible that the alder zone stretched higher up the mountains and further out on the coastal tundra than it does today. Similar movements of an alder zone seem to have occurred on tundras outside Labrador, both in the New world and the Old.

In eastern Labrador there have also been variations in humidity affecting both the vegetation and its deposits, presumably contemporary with similar variations of climate in the north of

Europe - at any rate towards the end of postglacial time. It seems as though the xerothermic phase in Labrador, terminating with heath horizon III, has been synchronous with the subboreal phase in Northern Europe.

[In the last century there have been variations in climate as follows:] In the north of Labrador the mean temperature for the year seems to have risen and the humidity probably sunk. This explains the present shrinkage of glacierettes, and also perhaps the drying up of the forest on land specially dependent on water. It seems too as if the drying up of surface of certain swamps has taken place over a whole region and may be connected with the climatic fluctuation of this century.

Similar phenomena have probably taken place during a postglacial warm period. Such a period might have favoured the forest in its struggle region by the sea except where it has locally dried up. As a result of the dryness, the formation of peat in the bogs has probably been of relatively small proportions.

Excerpts$^+$

882. WESTGATE, J.A. 1969. The Quaternary geology of the Edmonton area, Alberta. In: Pedology and Quaternary Research. Edited by: S. Pawluk. University of Alberta Press, Edmonton. pp. 129-151.

New data on the Quaternary stratigraphy of the Edmonton area are presented within the geological framework established by other workers.

The oldest Quaternary deposits in the Edmonton area are fluviatile gravels and sands, known as the Saskatchewan Gravels. ...Periglacial structures within the Saskatchewan Gravels, including ice-wedge casts, fossil sand wedges, involutions and once-frozen angular blocks of sand, clearly attest to some horizons accumulating under cold-climate conditions.

A grayish brown, dense clay loam till with some inclusions of stratified sand overlies the Saskatchewan Gravels or sits directly on bedrock. ...

The North Saskatchewan Valley contains several postglacial alluvial terraces. Little is known about the sedimentary sequence and chronology of the older and higher terraces but the lowermost two developed during the last 10,000 years. Mazama ash is present in the alluvium of the youngest terraces.

Mammalian remains from the youngest beds of the Saskatchewan Gravels suggest that the entire glacial succession is of late Pleistocene age.

pA.A.

883. WESTGATE, J.A., P. FRITZ, J.V. MATTHEWS, Jr., L. KALAS, L.D. DELORME, R. GREEN, and R. AARIO. 1972. Geochronology and palaeoecology of mid-Wisconsin sediments in west-central Alberta, Canada. 24th International Geological Congress, Abstracts: 380.

Twenty feet of massive, fine-grained fossiliferous sediments of Mid-Wisconsin age lie between laminated proglacial lacustrine silts and clays in a thick sequence of Pleistocene deposits exposed in the Smoky River Valley, near Watino, Alberta. Their age is indicated by C-14 dates on wood and peat: >38,000 years B.P. (GX-1207), 3 ft (1m) above base; 43,500 ± 620 (GSC-1020), at 4.5 ft (1.5 m); 35,500 ± 2,300 or 1,800 (I-2615), at 13 ft (4m); and 27,400 ± 850 (I-4878) at 18 ft (5.5m).

The sediments, with their contained pollen, molluscs, ostracods and insects, show that the depositional environment was the floodplain of a large meandering river where oxbow-type lakes developed and evolved at times into alkaline, eutrophic water bodies. Low AP pollen frequencies (mainly spruce) are commonly less than the NAP pollen (mainly grasses and sedges), suggesting an open vegetation with only scattered conifers. Ecosystem evolution of the oxbow lakes was sporadically interrupted by the influx of coarse detritus during floods;

the resultant freshening of lake water is closely monitored by the relatively low O^{18} content of mollusc shells. O^{18} (PDB) values range from -13 to -9.5 for *Lymnaea* sp., -12.7 to -8.2 for *Pisidium* sp., and -11.5 to -7.3 for *Gyraulus parvus* (Say). The higher values are typical of the forms that live in quiet, strongly evaporating water bodies in this area today. With the exception of a few individuals, insect, ostracod, and mollusc assemblages are very similar to those that occur in central Alberta today.

From this palaeoenvironmental reconstruction, it follows that Laurentide and Cordilleran glaciers must have been separated by a very wide "corridor" at this latitude throughout most of the Mid-Wisconsin interval.

A.A.

884. WEYL, P.K. 1968. The role of the oceans in climatic change: a theory of the ice ages. In: Causes of Climatic Change. Edited by: J.M. Mitchell, Jr. Proceedings VII Congress INQUA. Meteorological Monographs 8(30):37-62.

Changes in the surface salinity distribution in the World Ocean, by changing the extent of sea ice in the North Atlantic and Antarctic, can lead to climatic change. By reducing the water vapour flux across Central America, the salinity of the North Atlantic is reduced. If this change persists over a sufficient length of time, a glacial climate could be initiated. An examination of the "Little Ice Age" tends to confirm this hypothesis. A return to an interglacial climate may be the result of over-extension of glaciers followed by stagnation of the bottom water. Stagnation is terminated by geothermal heating at the ocean floor, followed by vertical mixing of the warmed, saltier water into the subarctic gyre of the North Atlantic. This, in turn, results in a reduction of sea ice and in climatic warming.

A.A.

885. WHITE, J.M., and R.W. MATHEWES. 1982. Holocene vegetation and climatic change in the Peace River district, Canada. Canadian Journal of Earth Sciences 19(3):555-570.

A sediment core from a pond on the Alberta Plateau in the Peace River district of British Columbia was studied using pollen analysis and radiocarbon dating. Percentage and influx diagrams were produced, and radiocarbon dates were corrected to calendar years to calcualte the sedimentation rate. The 231 cm core terminated in clay, and a basal date of 7250 ± 120 years BP was obtained, several thousand years after the recession of Glacial Lake Peace. The formation of the pond is interpreted as resulting from a climatic change, probably a transition from the peak of the Hypsithermal. Zone 1, from 7250 to 5500 years BP, is interpreted as representing a seasonal slough, with upland vegetation percentages consistent with a boreal forest. At about 5500 years BP a permanent pond with surrounding sedge wetlands was formed. Vegetation has been essentially modern during the last 3100 years. Measurements of spruce grains suggest the presence of black and white spruce throughout the pollen record. The formation of permanent ponds and wetlands on the Alberta Plateau at about 5500 years BP is thought to have been the most important vegetation change of the last 7000 years, which may have affected faunal and human populations.

A.A.

886. WHITE, J.M., R.W. MATHEWES, and W.H. MATHEWS. 1979. Radiocarbon dates from Boone Lake and their relation to the "Ice-free Corridor" in the Peace River District of Alberta, Canada. Canadian Journal of Earth Sciences 16(9):1870-1874.

Four new radiocarbon dates spanning the period of 10 740 ± 395 to greater than 30 000 BP from a core taken from the bed of high-level lake in the Saddle Hills of northwestern Alberta suggest that these hills escaped glacial overriding during late Wisconsinan glaciation.

A.A.

887. WILLIAMS, J. 1980. Anomalies in temperature and rainfall during warm arctic seasons as a guide to the formulation of climatic scenarios. Climatic Change 2(3):249-266.

Recently much concern has been expressed regarding the impact of an increased atmospheric CO_2 concentration on climate. Unfortunately, present understanding and models of the climate system are not good enough for reliable prediction of such impacts. This paper presents an analysis of recent climate data in order to illustrate the nature of regional temperature and rainfall changes in different seasons and to provide some guidance with regard to points which might be borne in mind when scenarios of future climate (especially those taking into account human impacts) are being formulated.

Since it is believed that an increased atmospheric CO_2 concentration will cause a warming and models and data suggest that the Arctic is more sensitive to climatic change than other latitudes, anomalies associated with warm Arctic seasons have been studied.

The regional temperature, precipitation and pressure anomalies in the northern hemisphere for the 10 warmest Arctic winters and 10 warmest Arctic summers during the last 70 years have been investigated. Even when the Arctic area is warm, there are circulation changes such that large coherent anomalies occur elsewhere, with some regions warming and some cooling. The 10 warmest Arctic winters were characterised by larger amplitude anomalies, in the Arctic and elsewhere, than the 10 warmest summers, illustrating the difference in response between seasons. The precipitation differences for the 10 warmest Arctic winters and summers show for North America large coherent areas of increase or decrease, which again differ according to season. However, in winter the differences are not statistically significant, while the differences in two areas are significant in summer.

A.A.

888. WILLIAMS, L.D. 1975. The variation of corrie elevation and equilibrium line altitude with aspect in eastern Baffin Island, N.W.T., Canada. Arctic and Alpine Research 7(2):169-181.

It has been common practice to estimate ice-age climates by calculating the difference in temperature, at an assumed lapse rate, between the elevation of the present snowline and that represented by the lowest corries (cirques) in a region. Such a procedure not only ignores many other factors which may affect corrie glacierization, but is actually incorrect, because the change in snowline for a given temperature change does not depend only on lapse rate. This study suggests that the variation of equilibrium line altitude (ELA) with aspect provides a climatic "signature" supplementary to that of lowest ELA. A method of computing heat and water balances on glaciers from climatic data is described and tested against observations on Baffin Island glaciers. This model is used to estimate ELA as a function of aspect in the Okoa Bay area of Baffin Island, using 1963 to 1972 climatic data, and then for two contrasting climates which have been suggested for early and late stages in the last glaciation. The results are compared with distributions of corrie glaciers and ice-free corries in the area.

A.A.

889. WILLIAMS, L.D. 1975. Effect of insolation changes on late summer snow cover in northern Canada. In: Long-term Climatic Fluctuations. World Meteorological Organization, Geneva, WMO-421:287-292.

The extent of snow cover which might have existed in the Canadian Arctic at 116 000 BP when Milankovich variations gave a summer radiation minimum at these latitudes, and just preceding the apparent large increase in snowfall and glacial maximum there, is estimated. The concepts and methods employed are outlined and the simulation results discussed.

G.A.

890. WILLIAMS, L.D. 1978. Ice-sheet initiation and climatic influences of expanded snow cover in Arctic Canada. Quaternary Research 10(2):141-149.

It has been suggested that the Laurentide Ice Sheet originated with extensive perennial snow cover, and that the snow cover affected climate so as to aid ice-sheet development. In this study, a large increase in extent of October 1st snow cover in the Canadian Arctic from 1967-70 to 1971-75 is compared to changes in October means of other climate variables. Over the area of snow-cover expansion, mean surface air temperature decreased by up to 3°C, mean 500-mbar height was lowered by over 60 m, and precipitation was increased by up to a factor of two. These effects, if applied to the entire summer, together with the temperature change computed by Shaw and Donn for a Northern Hemisphere summer insolation minimum (the Milankovich effect), can account for glacierization of the Central Canadian Arctic.

A.A.

891. WILLIAMS, L.D. 1978. The Little Ice Age glaciation level on Baffin Island, Arctic Canada. Palaeogeography, Palaeoclimatology, Palaeoecology 25(3):199-207.

Mapping of the perennial snow/ice cover which existed on Baffin Island about 300 years ago, by means of light-toned areas of sparse lichen cover visible on satellite photographs, has made it possible to map the Little Ice Age glaciation level (a type of snowline). Comparison with the modern glaciation level (which is 200-300 m higher) is not meaningful, for it is not necessarily in equilibrium with the present climate. However, energy/mass balance modelling gives a 1963-1972 mean "snowline" which roughly approximates the modern glaciation level, and a 1.5°C temperature decrease gives a similarly rough approximation to the Little Ice Age glaciation level. A more important observation, perhaps, is that the Little Ice Age glaciation level dipped westward, and in west Baffin Island and the Melville Peninsula it was only 100-200 m higher than extensive plateaus of the central Canadian arctic west of Baffin Island. This suggests that these plateaus would have been glacierized early in a glacial episode, and early glacierization of the central Canadian arctic west of Baffin Island. This suggests that these plateaus would have been glacerized early in a glacial episode, and early glacerization of the central Canadian arctic (by its effect on atmospheric circulation) has been considered to be important for inception of the North American ice sheet.

A.A.

892. WILLIAMS, N.E., and A.V. MORGAN. 1977. Fossil caddisflies (Insecta: Trichoptera) from the Don Formation, Toronto, Ontario, and their use in paleoecology. Canadian Journal of Zoology 55:519-527.

Chitinous parts of caddisfly larvae have been recovered from Sangamonian Interglacial silts and clays from the Don Valley brickyard Toronto, Ontario. These indicate that deposition took place at the mouth of a river. Various characteristics of this river, the large lake into which it flowed, and the watershed are deduced. It is suggested that the prognosis for paleoecological use of this insect group is good. By looking at sufficiently large assemblages of taxa it should be possible to deduce the type of water body, its size, temperature, substrate, depth, productivity, nature of the surrounding watershed, and its climate.

A.A.+

893. WILLIAMS, N.E., J.A. WESTGATE, D.D. WILLIAMS, A. MORGAN, and A.V. MORGAN. 1981. Invertebrate fossils (Insecta: Trichoptera, Diptera, Coleoptera) from the Pleistocene Scarborough Formation at Toronto, Ontario, and their paleoenvironmental significance. Quaternary Research 16(2):146-166.

Larval caddisfly, chironomid, and beetle remains have been recovered from the Pleistocene Scarborough Formation in the Toronto region of southern Ontario. Previous work on plant and animal remains from the Scarborough Formation suggests climatic conditions somewhat cooler than those of present-day southern Ontario. The mean July temperature at Toronto today is 20.5°C, and the mean annual temperature is 7.5°C. Terasmae (1960) suggested on the basis of pollen and plant macrofossils that most of the Scarborough beds were deposited during a boreal climatic regime with a mean annual temperature about 5.5°C (10°F) lower than present. This agrees well with our evidence from caddisfly, chironomid, and beetle remains from assemblages A and B. However, previous work on beetles from a locality (Cudia Park) 5 km west of site 1 (Morgan, 1972, 1975; Morgan and Morgan, 1976) has indicated that an even cooler, perhaps subarctic, climate existed during deposition of the upper part of the Scarborough Formation. The numerous northern boreal beetle species identified in the latter sediments were not found in assemblages A and B at site 1. It is likely, therefore, that significant climatic differences prevailed over the period during which the Scarborough Formation accumulated. We suggest that both aquatic and terrestrial insects are good indicators of macroclimate.

Excerpt

894. **WILLIAMSON, M.A. 1982. Distribution of recent Foraminifera on the Nova Scotian shelf and slope. (North American Paleontological Convention III, Abstracts of Papers). Journal of Paleontology 56(2, supplement):30.**

Surficial sediment samples from the Nova Scotian shelf and slope were examined from foraminiferal abundances in order to determine modern assemblage compositions, distributions, and limiting oceanographic parameters. Q mode factor analysis of the raw data reveals eight significant assemblages accounting for 89% of the initial data. Six of the assemblages occur on the shelf proper (<200 m) and are restricted to distinct physiographic regions. There appears to be a faunal boundary running obliquely across the shelf, with bank and basin assemblages north of the line being compositionally dissimilar to those in the south. This variation can be linked to the distribution and influence of bottom water characters. On the shelf edge a distinct fauna is recognized along with several progressively deeper occurring slope assemblages. The factor analysis enables down slope transport of components of shelf faunas to be recognized and accounted for. Implications for palaeoceanography of Eastern Canada marine Quaternary sequences are discussed.

A.A.

895. **WILSON, A.T. 1980. Isotope evidence for past climatic and environmental change. Journal of Interdisciplinary History 10(4):795-812.**

This article shows that records of interest to historians exist not only in written records but also in the chemical and isotope composition of stratigraphic deposits in cave, ocean, and lake sediments, tree rings, and ice sheets. Even today stratigraphic sequences may be recording some aspects of man's activity more accurately and more quantitatively than man himself.

A.C.

896. **WILSON, C. 1979. The warm season along the east coast of Hudson's Bay during the early nineteenth century. International Conference on Climate and History, University of East Anglia, Norwich, July 8-14. Abstracts, pp. 63-64.**

This paper describes part of a study of the nineteenth century climate along the east coast of Hudson's Bay based on the material in the Hudson's Bay Company and Royal Society archives. In 1814, the Hudson's Bay Company sent directives to those in charge of the Bay Posts to record relevant information concerning the food-producing potential of their local environment during the warm season; where possible, they were to keep a Meteorological Register. The archival material for the years 1814 to 1821 (the year of the union with the North West Company) thus provides a useful documentary basis for a climatic study.

Instrumental material in these Registers, for Great Whale River, Fort George and Eastmain, consists principally of temperature readings; only one or two include barometric values. Wind direction is also entered and remarks on state of sky, precipitation or extreme weather are included. The Post journals, Annual Reports and Correspondence ofen contain further comments, as well as remarks related to the impact of the weather.

The calibration of the temperature record has been approached from a physical and statistical standpoint, to incorporate both the systematic quantitative differences which might be expected as a result of changes in instruments and observing practices (given the distinctive radiative qualities of these northern sites), and an extended application of Canadian Quality Control procedures. The more subjective weather remarks are rated on a three- to five-point scale. In addition, an attempt has been made to incorporate comments on snow cover and ice, vegetation and agriculture, birds and animals, human ecology and damage to property by studying the research literature relating these phenomena to certain aspects of the weather. This material is integrated graphically.

Considering the historical evidence as a whole, the characteristics of the individual warm seasons are presented, with studies of certain periods of anomalous weather. From 1814 to 1821, the seasons show large fluctuations, with the possibility that in 1816 and 1817 they may have been colder than those on modern record. The results for the period are compared with tree-ring studies for this region, and with the results of others working in other areas. The early years of the nineteenth century in England were also beset by economic and social difficulties for business enterprises. The impact of the unfavourable weather from 1815 to 1817 on these marginal Bay communities made it virtually impossible to implement some of the Company's remedial policies. Some aspects of this impact are discussed.

A.A.

897. WILSON, C.V. 1982. The summer season along the east coast of Hudson Bay during the nineteenth century. Canadian Climate Centre, Downsview, Report 82-4:1-223.

There is evidence that the temperature observations for Whale River, Big River and Eastmain from 1814 to 1821 were taken with care, and are reliable and consistent within the limitations of the instrumentation, sites, instrument exposure and observing practices of the period. It is believed that in their corrected form they are accurate to within acceptable limits of error compared with the modern series at Great Whale, Fort George and Eastmain. As such, they indicate that the period was generally cooler than recent times, and that the summers of 1816 and 1817 were colder than any on modern record.

pA.C.

898. WILSON, L.R. 1946. Pollen evidence for tundra in the vicinity of Lake Superior and James Bay. American Journal of Botany 33(3):227. (Abstract).

In the United States no definite proof is at this time known from peat pollen studies for the existence of tundra at the time when the Pleistocene ice was melting. All basal deposits in peat bogs contain pollen of forest trees. This is considered to indicate that trees in the United States migrated northward almost as fast as the glacial ice wasted. Anticyclonic winds from the glaciers probably prevented pollen from being transported from more southern localities.

In the vicinity of lake Nipigon, and Cochrane, Ontario, peat bogs have been found that contain no tree pollen in their lowest levels. The peat is of tundral type, consisting of grasses, sedges, and mosses. It appears that the present tree line was extended northward from a position somewhere to the south of these bogs, after glacial Lake Objibway time.

A.A.

899. WILSON, M. 1975. Holocene mammalian faunas on the Northern Great Plains of North America. Quaternary Non-Marine Paleoecology Conference, University of Waterloo, Waterloo. Program and Abstracts.

The Late Glacial Northern Plains fauna includes eight extinct taxa of mammals. Radiocarbon dates on *Mammuthus* spp. remains at several sites suggest extinction about 10,000 years BP. Other extinctions may have been synchronous, but absolute dates are few. The timing of extinction allows climatic and human-overkill hypotheses to be considered; perhaps both factors were involved.

Bison underwent progressive reduction in size through Late Glacial, Pre-Boreal, and Boreal periods, but by 6500 BP were still very large. Large bison of later periods probably represent population extremes. The rate of diminution may have accelerated during Atlantic (Altithermal) times.

Faunal remains from early post-Atlantic times have a very modern appearance, with species in their modern ranges. The Sub-Boreal Cactus Flower Local Fauna from S.E. Alberta includes the characteristic forms *Antilocapra americana, Sylvilagus nuttallii*, and *Vulpes velox* as early as 4000 BP. If climatic change during the Atlantic interval was major (as the dwarfing of bison might suggest), readjustment of the fauna to "modern" conditions must have been rapid.

Although the diminution of bison suggests some climatic stress during the Atlantic, the evidence from subsequent faunas and from the few Atlantic-aged data favour an hypothesis that Atlantic stress was not extreme. Changes in the seasonality of storms and other aspects of the climate during this interval may have differentially affected various grassland mammalian species.

A.A.

900. WILSON, M. 1978. Holocene geology and archaeology of the Bow River Floodplain at Calgary, Alberta. American Quaternary Association, National Conference, Abstracts 5:181.

Drainage of Glacial Lake Calgary in Late Pleistocene times was followed by scouring of the Bow Valley to a bedrock surface. A subsequent Cordilleran ice rejuvenation 11,500 to 11,000 years ago resulted in deposition of thick gravels, by a braided river in the Calgary area. A date of 11,300 ± 290 yr BP (RL-757) on very large bison bones from these gravels in Calgary negates previous estimates of lake drainage as late as 9000 yr BP. Subsequent terraces at Cochrane were described by Stalker as cut terraces, but cut-and-fill sequences are present at Calgary. Probably two true terrace surfaces postdate the gravel fill surface at Calgary, with additional point bar sufaces complicating the sequence. A widespread soil and black A and red brown B is observed below Mazama Ash and seems to record a stable period of thick vegetative cover (open-canopy forest) from 10,000 to 8,400 years ago. Shortly after 8,400 years BP surface erosion was renewed, perhaps through deterioration of the vegetative cover, causing extensive valley-wall slope reduction and growth of valley-marginal fans. There is some evidence for limited incision of the Bow R. (ca. 2 m) since the Mazama ash fall.

The geologic picture suggests that early postglacial archaeological sites should be sought on the lake plain, rather than in the river valley. Scarcity of sites from the 8,400-to-10,000 BP period could reflect the density of cover and a relatively dispersed low-visibility human occupation. Communal bison kills appear shortly after 8,400 years BP, from which point sites are more abundant.

A.A.

901. WILSON, R.G. 1981. Climatic variations and their impact on British Columbia. In: Climate Change Seminar Proceedings. Regina, March 17-19. Canadian Climate Centre, Downsview. pp. 26-27.

"British Columbia is frequently characterized as a land of climatic differences and extremes. The Province encompasses coastal rainforests, interior deserts, northern boreal forests, and mountain-top glaciers. This diversity is a significant asset to British Columbia, but it also indicates a strong susceptibility to climatic variations."

"It is anticipated that increased variability and/or change of our existing climates in British Columbia would have major impacts in several resource and economic areas: water management, air management, fish and wildlife, marine resources, agriculture, forestry, transport, and tourism."

The author details research, data and practical applications objectives and stresses the need for cooperation between provincial and federal programs.

A.B.S.

902. WINN, C.E. 1977. Vegetation history and geochronology of several sites in south southwestern Ontario with discussion on mastodon extinction in southern Ontario. M.Sc. thesis, Brock University, St. Catherines, Ontario.

This study has three purposes: to establish a chronologically controlled vegetational history of a number of sites in south southwestern Ontario; to utilize the resulting data to support and/or add to the current understanding of Quaternary geology and stratigraphy, and the glacial and postglacial history of the Great Lakes in south southwestern Ontario; and to attempt to propose a possible explanation for the extinction of the mastodon in southern Ontario.

Palynological and geochronological analyses were conducted on material collected from eleven sites (east to west): Verbeke Mastodon Site, Woloshko Mastodon site, Walker Pond II, Pond Mill I, Lake Hunger Bog, Bouckaert Site, Mabee Site, Cornell Bog, Colles Lake I, Folden Mastodon Site and Forest Pond. Individual geochronologically controlled (where possible) vegetational histories were reconstructed for each of the sites investigated.

The results of the individual studies, when considered in overview, indicated the existence of an established closed boreal forest throughout south southwestern Ontario by 10,000 years BP. This evidence for a significant climatic change coincident throughout south southwestern Ontario supports the proposed age of 10,000 years BP for the Pleistocene/Holocene Boundary (Terasmae, 1972).

Remnant patches of 'open spruce parkland' persisted in small local 'wet' areas. It was in these areas that the mastodon was restricted during early Holocene time. With continued encroachment by the surrounding boreal forest, possibly speeded up by this browser's destructive feeding habits, the spruce enclaves shrank and the mastodon became extinct in southwestern Ontario.

The results of this thesis basically support Dreimanis' (1967, 1968) proposed 'Environmental-Climatic' theory for mastodon extinction.

It is suggested that increased dryness during the present interglacial compared to the climate of earlier interglacials may be the key to unravelling the problem of mastodon extinction in eastern North America.

A.A.

903. The Wisconsin Deglaciation of Canada. Edited by: J.B. Bird. Arctic and Alpine Research 5(3):163-238. 1973.

As chairman of the IGU/INQUA Symposium held at the 22nd International Geographical Congress, Montreal, Canada, August 1972, the editor provides an introduction to individual papers within this volume. Attention was "focussed on the period commencing when major signs of continuing deglaciation became evident, in eastern Canada, roughly 12,000 years ago--by which time the areas of the ice sheet had been reduced by approximately 30% from its maximum position, and already considerable areas in the south and especially the southwestern sectors had been uncovered." Relevant papers have been individually annotated.

A.B.S.

904. WISEMAN, M.A., H.C. FRITTS, and J. TERASMAE. 1976. Dendroclimatic inferences from Fort Chimo, northeastern Canada. American Quaternary Association, National Conference, Abstracts 4:165.

Eighty cross sections of *Larix laricina* (Du Roi) K. Koch were collected in August, 1974, on the northern treeline east of Hudson's Bay near Ft. Chimo, Ungava, Canada (lat. 58°22'N; long. 68°23'W). Crossdating of the ring widths is of classic quality with considerable high-frequency variation, but low-frequency variations in growth produce a first-order autocorrelation of 0.61. Data for measured radii from 18 trees were standardized by fitting a negative exponential or straight line to derive indices depicted in the figure. In a response function analysis, climatic data for 1947-1974 from Fort Chimo reduced 28% of the ring-width variance, and prior growth reduced 57%. Ring widths respond directly to warmer-than-average temperatures during seven months of the April-November period. Precipitation in the prior July, September, November, December, and the current June is inversely correlated with growth. Narrow rings are often accompanied by frost damage indicating freezing during the growing season. It may be inferred that there were persistent intervals of spring/summer/autumn cold in the first 65 years of the 19th century (see figure) and that the area has been experiencing a return to this cold condition in recent years.

A.A.

905. WOLLIN, G., G.J. KUKLA, D.B. ERICSON, W.B.F. RYAN, and J. WOLLIN. 1973. Magnetic intensity and climatic changes 1925-1970. Nature 242(5392):34-37.

The results are reported of correlations between short period changes in magnetism and climate, based on direct instrumental observations. Total intensity curves based on annual means correlated with 10-yr means of air temperature at the nearest weather stations. The intensity is decreasing at observatories in Mexico, Canada, and the United States while the climate is getting warmer. At observatories in Greenland, Scotland, Sweden, and Egypt the intensity is increasing whereas the climate is getting colder. Observations suggest that the trends in intensity from most of the magnetic observatories in the world with records over at least 30 yr correlate negatively with the 10-yr means of air temperature. The authors conclude that a close relationship links changes of the Earth's magnetic field and climate. This may be a direct cause and effect relationship but the possiblity that both the Earth's magnetic field and climate show parallel reactions to the processes in the sun cannot be excluded.

G.A.

906. World Climate from 8,000 to 0 B.C. Edited by: J.S. Sawyer. Proceedings of the International Symposium held at Imperial College, London, April 18-19. Royal Meteorological Society, London, 1966. 299 pp.

Contains 15 papers and introductory address given at this symposium held at Imperial College, London 18-19 April 1966: and deals particularily with the Arctic. [Relevent papers have been individually annotated.]

A.B.+

907. WORLD METEOROLOGICAL ORGANIZATION. 1976. The World Meteorological Organization's statement on climatic change. Environmental Conservation 3(3):227-230.

The WMO statement on climatic change stresses how man's welfare continues to be highly dependent on climate. Climate exhibits variations on all time-scales. Long term global trends are expected, but are obscured by shorter term and/or regional changes due to natural or man-made causes. An appended Technical Report by the WMO discusses past climates, physical causes of climatic fluctuations, effects of man's activities on climate, assessment of climatic developments in the next 100-200 yr, effects of climatic variability on the environment and man's activities, and future action.

G.A.

908. WRIGHT, H.E., Jr. 1964. Aspects of the early postglacial forest succession in the Great Lakes region. Ecology 45(3):439-448.

Pollen diagrams of lake sediments imply that during fluctuating retreat of the Wisconsin ice sheet the Great lakes region was dominated by a spruce forest that may have contained some thermophilous deciduous trees like ash, elm, and oak but contained no pine and little birch, the two genera that today are such common associates of spruce in the Boreal Forest of Canada. Following relatively rapid destruction of this spruce forest about 10,500 years ago, presumably as a consequence of the climatic warming, birch and pine apparently invaded the area and were followed in rapid succession by elm, oak, and other deciduous trees. Although forest composition cannot be described in detail, the almost certain absence of any type of pine from the late-glacial forest requires special explanation. The hypothesis here presented proposes that during Wisconsin glaciation jack pine was unable to follow spruce in a general southward migration across the Great Lakes region to the central United States but took refuge instead in the Appalachian Highlands, and that during late-glacial time the versatile spruce was such an adaptable pioneer on deglaciated ground that it soon formed a closed forest. Birch and especially pine, far removed in their glacial refuges, were slower migrants and did not reach the western Great Lakes area in quantity until the spruce forest deteriorated. The subsequent succession of elm and oak may also reflect relative rates of migration from glacial refuges.

A.A.

909. WRIGHT, H.E., Jr. 1971. Retreat of the Laurentide Ice Sheet from 14,000 to 9000 years ago. Quaternary Research 1(3):316-330.

The intricate pattern of moraines of the Laurentide ice sheet in the Great Lakes region reflects the marked lobation of the ice margin in late Wisconsin time, and this in turn reflects the distribution of stream-cut lowlands etched in preglacial times in the weak-rock belts of gentle Paleozoic fold structures. It is difficult to trace and correlate moraines from lobe to lobe and to evaluate the magnitude of recession before readvance, but three breaks stands out in the sequence, with readvances at about 14,500, 13,000, and 11,500 years ago. The first, corresponding to the Cary advance of the Lake Michigan lobe, is represented to the west by distant advance of the Des Moines lobe in Iowa, and to the east by the overriding of lake beds by the Erie lobe. The 13,000-year advance is best represented by the

Port Huron moraine of the Lake Michigan and Huron lobes, but by relatively little action to west and east. The 11,500 year advance is based on the Valders till of the Lake Michigan lobe, but presumed correlations to east and west prove to be generally older, and the question is raised that these and some other ice advances in the Great Lakes region may represent surges of the ice rather than regional climatic change. Surging may involve the buildup of subglacial meltwater, which can provide the basal sliding necessary for rapid forward movement. It would be most favored by the conditions in the western Lake Superior basin, where the Superior lobe had a suitable form and thermal regime, as estimated from geomorphic and paleoclimatic criteria. The Valders advance of the Lake Michigan and Green Bay lobes may also have resulted from a surge: the eastern part of the Lake Superior basin, whence the ice advanced, has a pattern of deep gorges that resemble subglacial tunnel valleys, which imply great quantities of subglacial water that may have produced glacial surges before the water became channeled.

A.A.

910. WRIGHT, P.B. 1970. Portrait of climatic change (sources: Author, Department of Oceanography, University of Hawaii, Honolulu; or T.D. Davies, Environmental Sciences, University of East Anglia, Norwich, England). c40 pp.

A survey of the field of climatic change and related topics and a review of recent books. Designed for the non-climatologist or teachers, the booklet includes details of 16 books published since 1966 whose central theme is climatic change, assessed in terms of content, comprehensiveness and level of readership. Comments are also made about some 50 additional books and reports.

G.A.

911. YAPP, C.J., and S. EPSTEIN. 1977. Climatic implications of D/H ratios of meteoric water over North America (9500-22,000 B.P.) as inferred from ancient wood cellulose C-H hydrogen. Earth and Planetary Science Letters 34(3):333-350.

δD and δ^{13}C values have been measured for unexchangeable hydrogen and the total carbon of cellulose extracted from 40 North American ^{14}C-dated trees that range in age from 9500 to 22,000 years B.P. Meteoric waters which precipitated over ice-free regions of North America in the interval 14,000-22,000 B.P. had more positive δD values than corresponding modern waters by an average of 19 $^0/_{00}$. Lower ocean temperatures and smaller temperature gradients than exist at present between ocean and ice-free North America are indicated for the late Wisconsin glacial maximum. This is compatible with warmer winters and cooler summers for this glacial period. The δD value of the North American ice sheet during the Late Wisconsin maximum was approximately -100 $^0/_{00}$ as determined from the inferred δD values of the waters of proglacial lakes Agassiz and Whittlesey. From this figure the increase in δ^{18}O of the oceans during the glacial maximum can be calculated to have been +0.8 $^0/_{00}$. At the point where they began to move over the ice, air masses supplying moisture to the North American ice sheet contained a little more than 50% of their original moisture content, which is a much greater percentage than exists in air masses supplying the modern Greenland and Antarctic ice sheets. This relatively vapor-rich air coupled with lower summer temperatures, which reduced ablation, probably contributed to the maintenance and growth of the ice sheet. The transition from glacial to interglacial conditions in North America was rapid and occurred within a 2000-3000-year interval. However, the transition may not have been synchronous over North America.

G.A.

912. ZOLTAI, S.C., and C. TARNOCAI. 1975. Perennially frozen peatlands in the Western Arctic and Subarctic of Canada. Canadian Journal of Earth Sciences 12(1):28-43.

Perennially frozen peatlands were divided into five morphological types: peat plateaus, polygonal peat plateaus, palsas, fen ridges and lowland polygons. One hundred and eight different peatlands were cored, measured and sampled. The internal structure of all but the lowland polygons suggests that the peat was deposited in wet fens unaffected by permafrost, and the permafrost developed only after a thin layer of *Sphagnum* covered them. The lowland polygons evolved in a permafrost environment. The study area was divided into four regions on the basis of predominance of different peatlands forms.

The radiocarbon ages of basal organic deposits show that the continental glacier had melted from the areas east of the mountains and initial organic material accumulation began between 14400 and 10000 years ago. The main peat build-up began one to several thousand years later, mainly between 10500 and 5600 radiocarbon years ago. Regional trends are difficult to discern, as local circumstances such as basin formation, erosion, base drainage, etc. played a dominant role in permitting the peat accumulation. Generally, the oldest basal peat deposits occur near the mountains and the ages tend to be younger eastward.

The age of the surface peat 2710 and 2650 years before present (BGS 147;218), indicate the time of establishment of *Sphagnum* caps at those sites, followed by permafrost development. The period around 3500 years B.P. and 2400 B.P. were times of climatic deterioration in northern Canada (Nichols, 1969), and the dates 2710 and 2650 B.P. are probably related to these fluctuating climatic conditions.

The meager data permit only speculation on the chronosequence of regional peatland development. Apparently, peatland development began soon after the melting of the continental glaciers and peat accumulation proceeded at a rapid rate especially beginning about 8000 years ago. Permafrost was present, but it was less widespread both in the north and in the south than at the present. A minor cooling some 3000 to 4000 years ago produced an increase in peat plateaus, restricting peat accumulation to unfrozen fens. Polygonal peat plateaus probably developed at this time. Peatlands in the tundra were continuously subject to permafrost after the melting of continental glaciers.

In the more southern parts of Canada the melting of continental glaciers was followed by a dry and warm period, permitting only restricted peat accumulation between 7500 and 6000 years ago (Terasmae, 1972). This was followed by a wetter and then a cooler period when rapid peat accumulation took place. In the north, however, the climate was favourable for peat accumulation during the warm period (8000 to 4000 years ago), but peat formation was reduced during the cooler period beginning about 4000 years ago. Such shifting of regions of peat accumulation in accordance to climatic changes occurs throughout the peatland regions of Canada (Terasmae, 1972).

A.A.

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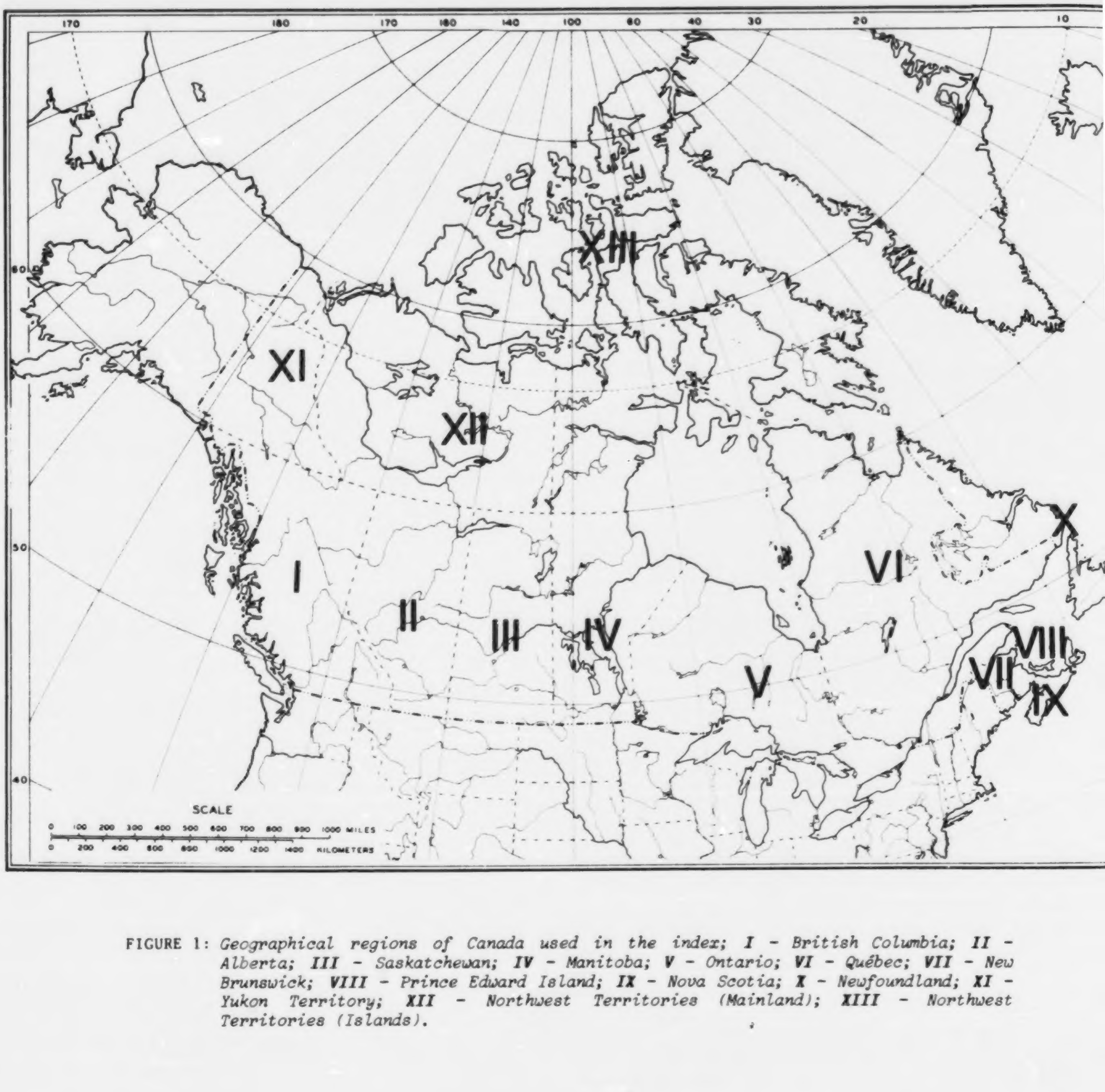
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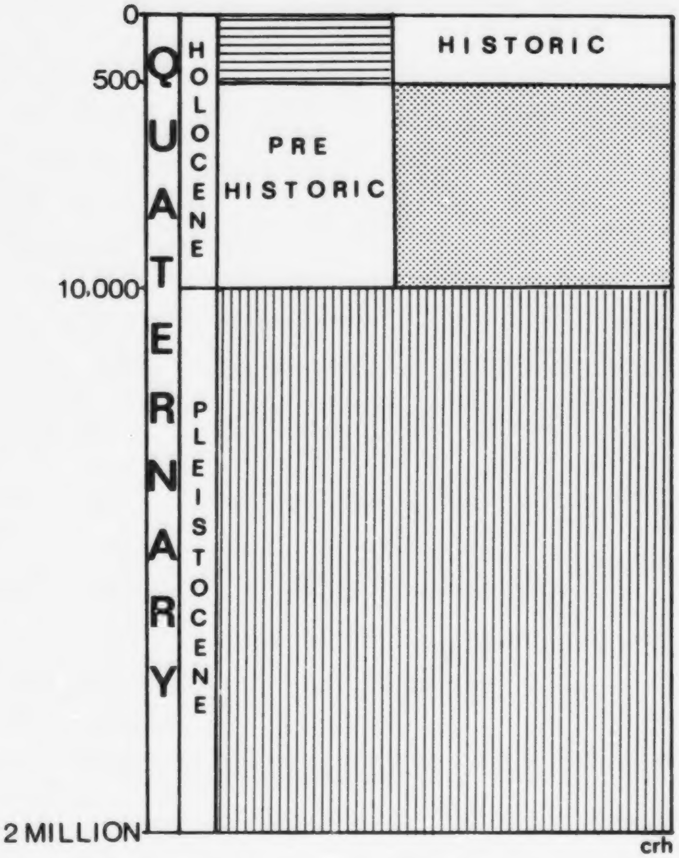
FIGURE 1: *Geographical regions of Canada used in the index; I - British Columbia; II - Alberta; III - Saskatchewan; IV - Manitoba; V - Ontario; VI - Québec; VII - New Brunswick; VIII - Prince Edward Island; IX - Nova Scotia; X - Newfoundland; XI - Yukon Territory; XII - Northwest Territories (Mainland); XIII - Northwest Territories (Islands).*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10,000
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PLEISTOCENE
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HISTORIC
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FIGURE 2: *Geological time periods used in the index. Numbers on left represent years B.P. (approximate).*

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50 72 74 104 112 145 168 183 184 189 231 232 235 307
395 427 435 441 444 490 494 592 593 595 596 597 613 656
663 681 698 720 778 803 811 817 866 872 892 893 898 902

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138 174 182 184 186 258 347 388 828 872

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15 44 50 51 72 74 104 145 231 235 307 395 427 437
440 441 443 444 445 556 559 560 561 613 616 617 654 663
698 701 720 725 738 778 803 806 810 811 828 832 833 836
866 878 898 902

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443 444 697

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14 65 100 322 342 568 656 812

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1 65 100 568

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1 5 59 220 234 392 416 417 501 620 692 721 798 820

Pleistocene

2 39 56 393 487 690 700 771 803

Holocene

20 28 37 40 45 54 66 72 103 169 225 257 277 311
317 327 342 354 387 388 389 474 547 558 562 611 612 613
641 645 647 652 656 664 672 683 685 686 687 710 711 712
713 714 715 717 718 719 720 722 775 776 812 818 839 866

Holocene - Prehistoric

4 51 97 139 174 182 184 185 187 224 255 258 335 347
353 384 385 386 413 475 485 486 614 651 684 691 699 772
805 809 826 829 832 835 872 909

Holocene - Historic

16 55 102 115 135 180 188 321 360 390 391 406 548 585
668 671 716 738 789 878 890 896 897 904

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360 391 475 571 647 798

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54 55 59 102 180 220 738

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2 174 182 184 486 547 754 872

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691 692 711 909

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1 2 4 39 139 417 614 690 803

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691 699 771 832 890 909

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4 51 66 103 311 321 335 487 547 614 672 684 692 700
803 818 829

Paleoecology

4 66 72 169 184 317 321 327 353 384 386 417 474 547
548 562 611 612 613 614 641 656 664 683 684 685 686 687
710 711 712 713 714 715 716 717 719 720 722 776 803 829
866 872

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1 2 174 182 184 187 258 347 353 385 386 388 389 652
692 872

Palynology

4 20 37 51 66 72 103 169 220 327 342 474 485 501
548 558 562 611 612 613 614 620 641 645 647 664 683 685
686 687 690 692 700 710 711 712 713 714 715 716 717 718
719 720 721 722 738 772 775 776 803 805 809 812 820 826
829 832 835 866 878

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40 185 234 257 387 485 547 691 699

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203 355 455 748 786

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459 606 613 676 728 740

Holocene - Prehistoric
144 204 222 408 734

Holocene - Historic
136 142 170 193 194 195 314 429 452 604 689 859 868 878

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196 197 198 295 348 349 350 398 460 493 495 499 703 768
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94 189 192 212 352 407 412 550 555 748 766

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96 217 218 219 319 428 527 528 613 677 732 797 819

Holocene - Prehistoric

146 551 552 731 733

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189 192 349 350 352 398 407 412 499 551 555

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24 126 156 162 163 288 318 348 351 394 410 416 665 808
821 824

Pleistocene

2 205 211 352 361 415 512 517 518 679 749 787 889

Holocene

17 28 30 61 63 65 67 206 307 326 342 397 564 637
644 645 646 782 822 827 863

Holocene - Prehistoric

18 33 124 343 456 500 608 704 799 903 908 912

Holocene - Historic

73 90 102 134 210 238 239 305 391 424 508 509 585 588
791 846 848 849 852 853 855 860 862 868 887 890

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48 56 74 149 171 205 235 291 352 361 415 517 518 535 771 851 873

Holocene

21 72 122 123 217 218 307 319 326 388 490 641 728 765 770 794 825

Holocene - Prehistoric

18 44 53 97 124 144 173 182 185 233 379 403 408 485 552 557 596 655 699 704 747 750 899 908 909

Holocene - Historic

90 111 120 188 210 266 281 302 304 305 316 424 454 585 626 662 842 874 878

General

344 410 498 517 518 825 856

Archaeology

398 408 794

Atmospheric

90 122 626 911

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276 285 288 292 293 297 348 349 362 398 410 416 472 481
484 573 600 673 694 695 696 730 763 764 792 815 854

Pleistocene

64 129 166 241 250 261 267 268 269 271 272 274 290 331
430 477 483 512 570 587 599 658 659 749 752 779 861

Holocene

21 61 80 93 143 164 206 217 286 296 298 364 528 547
632 633 634 653 682 723 742 880 881

Holocene - Prehistoric

75 77 173 343 379 482 552 601 745 747 799 864 877 906

Holocene - Historic

16 90 92 95 110 114 128 131 176 237 238 242 243 244
245 251 252 253 300 301 303 320 329 411 436 451 462 477
479 510 530 532 533 567 624 675 708 756 758 793 860 868
869 870 871 875 879 884 905

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52 58 93 95 117 121 140 161 164 221 228 241 262 290
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155 201 240 260 267 268 271 376 430 510 547 587 658 745
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80 348 601 854

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